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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PILOT CURRICULUM AND INSTRUCTOR'S GUIDE EMPHASIZING SAFETY IN COMPRESSED GASES AND CRYOGENIC LIQUIDS

By

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MANNED SPACECRAFT CENTER
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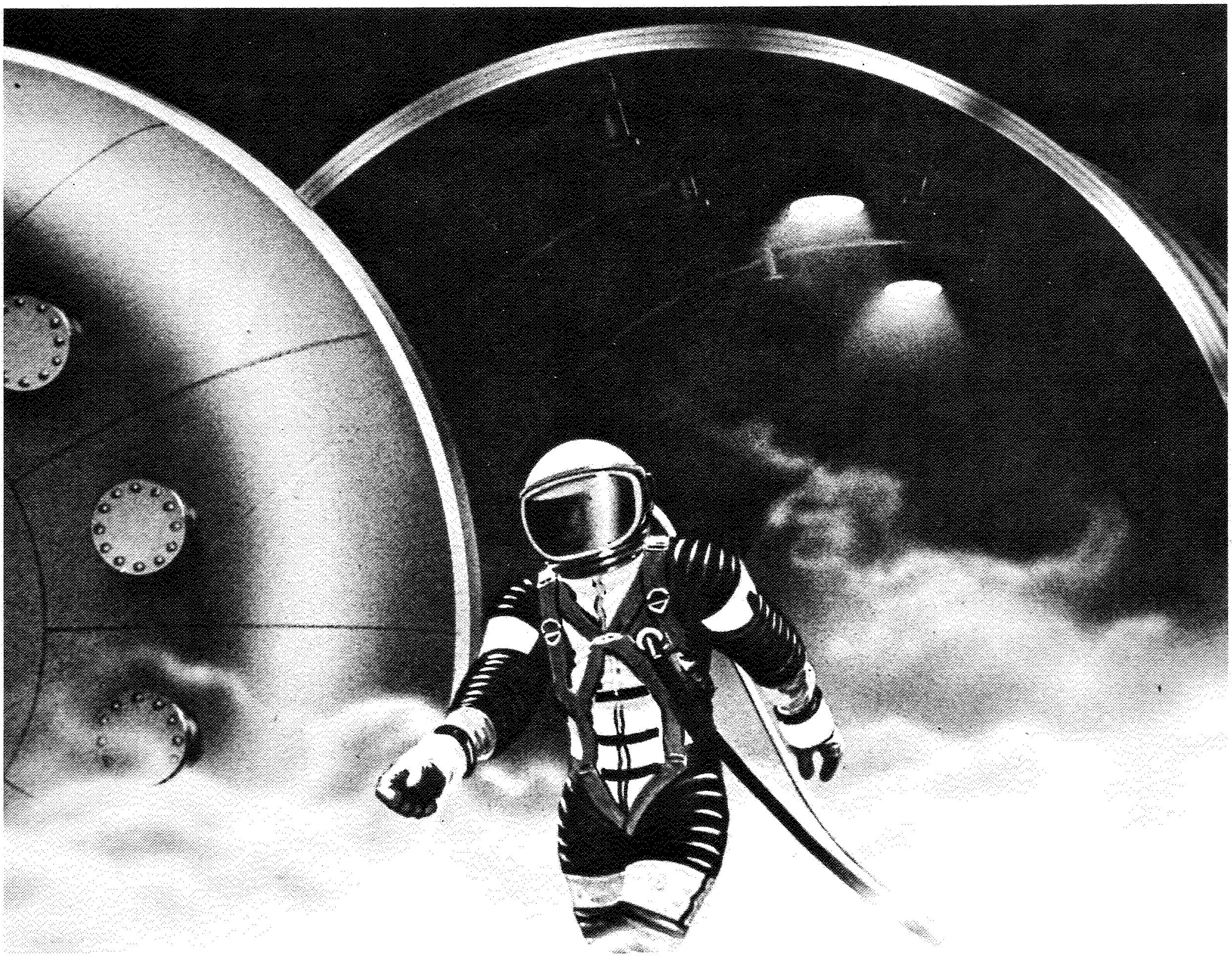

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ACKNOWLEDGMENTS

Space exploration — the frontier of the future — requires increased development and implementation of the science and technology that have already taken place in this twentieth century. In the vanguard of this dynamic technical progress, and critical to man's landing on the lunar surface and safely returning to this planet, are continuing developments in industrial gases and cryogenics.

To help safely facilitate the progress being made in one area of space exploration — manned space flight — this safety curriculum on compressed gases and cryogenic liquids has been developed. This curriculum has been prepared under unusual and difficult conditions primarily because sensory materials of instruction, peculiar to the emerging needs of this particular Center are, for the most part, nonexistent.

Despite the dearth of available materials, considerable assistance has been obtained from the armed services, different government agencies, business and industry. Without the splendid spirit of cooperation and interest provided by industry, this course would not have been possible. Among the major industrial contributors to this Guide are: Air Reduction Sales, Inc.; Air Products and Chemicals, Inc.; Black, Sivalls, and Bryson, Inc.; Cryodyne, Inc.; Linde Division of Union Carbide Corporation; Matheson Chemical Co.; Mine Safety Appliance Co.; North American Aviation; Southwestern Cryogenics; and Webber Manufacturing Co., Inc. To each of these groups we wish to acknowledge our most sincere gratitude.

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Though the numerous contributions of others to this Curriculum Guide are sincerely acknowledged, the authors are cognizant of the fact that this "Pilot Guide" may have many faults — faults which, hopefully, will be brought to the attention of the Manned Spacecraft Center Safety Office or the authors, so that appropriate and beneficial modifications may be made.

A MESSAGE TO THE USERS OF THIS CURRICULUM GUIDE

Introduction

This Curriculum Guide has been prepared to assist both the instructor(s) and those persons interested in the presentation of various safety aspects of industrial gases and cryogenics liquids. In this course offering, safety will be emphasized as concerns gases and cryogenics liquids at the Manned Spacecraft Center, Houston, Texas. Those who participate in the course will become familiar with not only the gases and cryogenics materials, but also, publications, audiovisual aids, equipment and devices in this field.

Course Objectives

Course participants should understand and strive to attain the goals established for each topic. The knowledge to be learned and the skills to be acquired will be stated in each topic of this Guide. However, it will be incumbent upon both the instructor and course participants to insure that objectives are understood and specific goals attained.

Instruction and Application

Various instructional approaches are recommended for the presentation of different topics which comprise the course. Each instructional approach used should help stimulate interest and motivate learning. New ideas and suggestions to present this course more effectively are sought, and after being "tested," should be used to optimum advantage. Class discussions are primarily related to practical gaseous and cryogenic materials. While various theories pertaining to gases and cryogenics are considered to be significant, it is the area of safety which will be of the utmost importance and the area in which maximum stress will be placed. Consequently, the primary reason for including theoretical aspects in this course will be to assist the course participant to perform practical work by teaching the safety implications concerned.

Course Aids, Quizzes, and Outside Study

The proper utilization of audiovisual aids, including the demonstration of equipment devices and materials, should facilitate learning and development of proper attitudes. Where skill is to be acquired, "learning by doing" will prove helpful.

Quizzes have been specifically designed to further the learning of each course participant. These quizzes will be taken and may be graded by course participants to help guide them in the progress of their work. Discussion of these quizzes will also enable the instructor to modify or reinforce certain areas of instruction, as appropriate.

Outside study is recommended but not considered mandatory for this course. Most of the study will entail reviewing classwork already covered and reading handout materials furnished by the instructor. Though selected aspects of handout materials will be covered in class by the course instructor, it is anticipated that course participants will pursue these printed materials outside of class.

Safety

A listing of publications, not sensory materials of instruction, is included in this curriculum. These publications and sensory materials, along with the instructor's own intimate knowledge of this Center, will provide a background, wholly or in part, for gaseous and cryogenics safety precautions at MSC. Safety must be considered a vital part of each topic or instruction so that course participants will develop safe working habits.

Suggested Curriculum Outline

for

Session 1

COURSE OVERVIEW AND INTRODUCTION

A. Objectives

1. To register course participants and provide the necessary information concerning course needs and objectives
2. To develop proper attitudes, understandings, and appreciation pertaining to the presentation of this course
3. To acquaint participants with the scope and magnitude of the course
4. To stress the vital role of safety throughout the entire course

B. Suggested session coverage

1. Introduction of instructor(s) and the course itself
2. Registration of each class participant
3. Discussion of the need for this course
4. Course coverage, presentation length, and evaluation
5. General methods and techniques of course presentation to the audience concerned
6. Pretest
7. Summary and distribution of materials

C. Reference material and printed matter

1. Manned Spacecraft Center Safety Manual (MSCM 1700)
2. Registration form

3. "Precut, prebent, tent-like" forms for course participant identification

4. Course assessment forms

D. Audiovisual aids

1. Display of articles, brochures, and periodicals to be used in this course

2. Felt pens or comparable materials

3. Transparencies (appendix A)

    a. S-67-4129 "Course Coverage"
    b. S-67-4130 "Some Instructional Techniques and Methods"
    c. S-67-4352 "Major Topics"

E. Course pretest and related answer sheet — appendix A

F. Suggested lesson plan and accompanying suggestions for the instructor — appendix A

G. Selected support materials

1. Appraisal of the safety course

2. Registration data sheet

3. Transparencies

Suggested Curriculum Outline

for

Session 2

THE ATMOSPHERE

AND

THE ROLE OF QUALITY ASSURANCE IN THE HANDLING OF COMPRESSED GASES

A. Objectives

1. To review the properties and composition of air
2. To correlate the relationship between atmospheric elements and manned space flight projects
3. To familiarize class participants with the role that quality assurance plays with compressed gases

B. Suggested session coverage

1. Review of the preceding session, especially pretest highlights
2. Air and its properties
3. Composition of air
4. Atmospheric layers
5. Atmospheric elements with which the Center is particularly concerned
6. The role of quality assurance in handling compressed gases
7. Session assessment
8. Résumé of session and announcement of topic(s) for next session
9. Distribution of handout materials

C. Reference material and printed matter

1. Texts and manuals — any general encyclopedia or physical science text pertaining to the atmosphere

2. Catalog — "Atmosphere Chart" and "High Altitude Chart," Webber Manufacturing Co., Catalog No. 6600, Indianapolis, Indiana, 1965, pp. 1 and 41

3. Miscellaneous — (please refer to Table of Contents — Glossary)

D. Audiovisual aids

1. Graphics displays

   a. S-67-35692 "Atmospheric Layers and Manned Space Flight Penetrations"
   b. S-67-35693 "Gaseous Content of Dry Air"
   c. S-67-35694 "Air"
   d. S-67-20407 "Aerial View of Manned Spacecraft Center"

2. Transparencies

   a. S-67-84 "Atmospheric Layers"
   b. S-67-87 "Atmospheric Elements with which MSC is Particularly Concerned"
   c. S-67-88 "Air"
   d. S-67-97 "Atmospheric Chart"
   e. S-67-4351 "High Altitude Chart"
   f. S-67-4616 "Comparative Temperature Scales"

E. Suggested lesson plan and accompanying suggestions for the instructor — appendix B

F. Session quiz and related answer sheet — appendix B

G. Selected support materials

1. An overview of "The Atmosphere and Atmospheric Layers"

2. Graphics displays and transparencies

Suggested Curriculum Outline

for

Session 3

HANDLING COMPRESSED GASES

A. Objectives

1. To become acquainted with the different types and applications of compressed gases used at the Center

2. To become familiar with the need for handling compressed gases safely and to implement this need

B. Suggested session coverage

1. Review of the preceding session and introduction to the session

2. Types of compressed gases used at the Center

3. Need for handling compressed gases safely

4. High-pressure cylinders and safety in handling them

5. Examination of actual compressed gas cylinders

6. Session assessment

7. Summary and announcement of topic(s) for the next session

8. Distribution of handout materials

C. Reference material and printed matter

1. Texts and manuals

   a. Handbook on Compressed Gases. American Gas Association, Rhinehart and Co., Inc., New York, New York, 1966. Part III

   b. Manned Spacecraft Center Safety Manual. (MSCM 1700), Part 5, Subpart 19

2. Pamphlets and brochures

   a. "Handling, Transportation and Storage of Compressed Gas Cylinders and Liquefied Gas Containers," Form 11-641-B, Linde Division, Union Carbide Corporation, New York, New York, 1966. pp. 1-8

   b. "Safe Handling of Compressed Gases in the Laboratory," Reprinted from the Third Edition of the Matheson Gas Data Book, The Matheson Company, Inc., East Rutherford, New Jersey, 1961. pp. 1-13

D. Audiovisual aids

1. Displays

   a. S-67-35691 "Using Compressed Gases"
   b. S-67-20407 "Aerial View of the Manned Spacecraft Center"

2. Equipment

   a. Three or more empty, though compatible, high-pressure cylinders (typical of those used at the Center)
   b. Dollies and/or an appropriate wheel-cylinder cart

3. Film — "Working with Compressed Gases"

4. Opaque projection material

   a. "Location and Types of Compressed Gases Used at the Manned Spacecraft Center"
   b. "Color Code for Cylinders," Manned Spacecraft Center Safety Manual, (MSCM 1700), Part 6, Subpart 2
   c. S-67-20077 "Proper Cylinder Handling and Storage"

5. Slides — "Keeping Cylinders Safe"

6. Transparencies

   a. S-67-86 "Compressed Gas Cylinders" (1 of 2)
   b. S-67-4128 "Compressed Gas Cylinders" (2 of 2)
   c. S-67-458 "Cylinder Size Chart"
   d. S-67-454 "Compressed Gas ... Fittings"

E. Suggested lesson plan and accompanying suggestions for the instructor — appendix C

F. Selected support materials

1. Script for slide presentation, "Keeping Cylinders Safe"

2. Discussion suggestions for film, "Working with Compressed Gases"

3. Opaque projection materials and transparencies

G. Session quiz and related answer sheet — appendix C

Suggested Curriculum Outline

for

Session 4

COMPRESSED GASES AND RELATED ASPECTS

A. Objectives

1. To become familiar with the safe handling of compressed gases used at the Center

2. To gain awareness of the location and operation of the central gas storage facility of the Center (building 381)

3. To become cognizant of the location, use, and safety aspects of larger high-pressure gas storage systems, both fixed and portable

4. To stress the safety aspects of cylinder overpressure protection

5. To emphasize the safety aspects of the backpack life support system

B. Suggested outline of instruction

1. Functions and related aspects of the central gas storage facility of the Center

2. Utilization of large, high-pressure gas storage facilities at the Center

3. The use of primary and secondary relief devices for overpressure protection on storage tanks

4. Utilization of life support systems at the Center

5. Review of safe handling of compressed gas cylinders

6. Session assessment

7. Summary and distribution of handout materials

C. Reference material and printed matter

1. Texts and manuals

   a. Handbook on Compressed Gases, American Gas Association, Reinhold Publishing Corp., New York, New York, 1966, Part III

   b. Manned Spacecraft Center Safety Manual (MSCM 1700), Part 5, Subpart 19

2. Pamphlets

   a. "An Introduction to Overpressure Protection with BS&B Safety Heads," No. 77-651, Black, Sivalls & Bryson, Kansas City, Missouri, May, 1965, pp. 1-8.

   b. "Dimensional Drawings: Compressed Gas Cylinder Valve Outlets and Connections," The Matheson Chemical Co., East Rutherford, New Jersey, undated, pp. 1-8.

   c. "High-Pressure Safety" and "High-Pressure Systems and Safety," both booklets for Course No. C-217, High-Pressure Systems and Safety, developed by Eaken, Ralph L., Development and Training Department 41-018, Space and Information Systems Division, North American Aviation, Inc., unpublished, January 1964, pp. 1-50 and 1-21, respectively.

   d. "How Safety Heads Paced the State of the Art," The Safety Header, Vol. 1, No. 4, Black, Sivalls & Bryson, Inc., Kansas City, Missouri, Winter 1964, p. 3.

   e. "How to Protect Against Overpressure with BS&B Safety Heads," Publication No. 77-650, Black, Sivalls & Bryson, Inc., Kansas City, Missouri, Second Printing, July 1964, pp. 1-64.

   f. Wood, L. E., "Rupture Discs," reprinted from Chemical Engineering Progress, Vol. 61, No. 2, February 1965, pp. 93-97.

3. Catalogs

   a. "Industrial Gases and Cryogenic Fluids," Catalog No. 300, Air Reduction Co., Inc., New York, New York, December 1963, pp. 1-28.

   b. "Bulk Gas Delivery System," Catalog No. 450, Air Reduction Co., Inc., New York, New York, November 1964, pp. 1-15.

D. Audiovisual aids

1. Equipment

   a. Empty, though compatible, cylinders, properly secured for both safety and display purposes

   b. Backpacks, such as those made by Mine Safety Appliance, Scott, SurvivAir, and so forth.

2. Exhibit — pegboard display on "Over Pressure Safety Devices"

3. Field Trip — (See lesson plan in appendix C and Field Trip appendix M, section 3.)

4. Graphics display — S-67-20407 "Aerial View of the Manned Spacecraft Center"

5. Opaque projection materials

   a. S-67-29818 "Central Gas Storage Facility"
   b. S-67-29819 "Central Gas Storage Facility"
   c. S-67-36445 "Safety Office Secretaries — Over Pressure Safety Devices"
   d. S-67-36443 "Over Pressure Safety Devices Pegboard Display"
   e. S-67-20727 "Safe Handling of Industrial Gases"
   f. S-67-44002 (Untitled) Repressurization Tanks for Space Simulation Chambers

6. Transparencies

   a. S-67-85 "Compressed Gas Cylinders" (See appendix C.)
   b. S 67-86 "Compressed Gas Cylinders" (See appendix C.)

E. <u>Suggested lesson plan and accompanying suggestions for the instructor — appendix D</u>

F. <u>Session quiz and related answer sheet — appendix D</u>

G. <u>Selected support materials</u>

1. "Highlights from a Presentation on Over Pressure Protection for Cylinders and Vessels"

2. Exhibit, opaque projection materials, and transparencies

Suggested Curriculum Outline

for

Session 5

INTRODUCTION TO CRYOGENICS

AND

LIQUID OXYGEN

A. Objectives

1. To become familiar with the developments in the cryogenics field, especially in the aerospace field.

2. To become further acquainted with cryogenic materials, particularly liquids at this Center.

3. To provide a thorough understanding of the need for implementation of cryogenic safety precautions and measures at this Center.

4. To become familiar with a typical cryogen, liquid oxygen (LOX).

B. Suggested session coverage

1. Overview of the cryogenics field

2. Cryogenic liquids, including materials, used at the Center

3. General safety precautions pertaining to cryogenic materials

4. Cryogenic system design

5. Review of applicable properties of the atmosphere

6. Properties, characteristics, and related aspects of liquid oxygen (LOX)

7. Safety and handling measures of LOX

8. Session assessment

9. Summary and distribution of materials

C. <u>Reference material and printed matter</u>

1. Texts and manuals — <u>Manned Spacecraft Center Safety Manual</u> (MSCM 1700), Part 5, Subpart 9, Liquid Oxygen.

2. Periodicals and reports

a. Kobrin, C. L., "Industry's New World of Ultracold," <u>Iron Age</u>, Vol. 191, No. 11, March 14, 1963, pp. 81-88.

b. Majoras, John; Navickas, John; and Sarlat, Irvin M., "Present State-of-the-Art in Designing for Storage of Cryogenic Propellants in Space," <u>Cryogenic Technology</u>, Vol. 2, No. 4, Cryogenic Technology Publications, Inc., Bel Air, Los Angeles, California, November/December 1966, pp. 137-141.

c. Parish, Douglas C., "The Three C's of Cryogenics," <u>Welder's World, Inc.</u>, Houston, Texas, September 1965, p. 7.

d. Parker, Jerold D., "Basics of Cryogenic Engineering," <u>Oil and Gas Equipment</u>, Vol. 13, No. 3, An Oil and Gas Journal Publication, Tulsa, Oklahoma, 1967, pp. 1-6.

e. Peckner, Donald and Riley, Malcolm W., "The Role of Materials in Cryogenics," <u>Materials in Design Engineering</u>, Vol. 54, No.1, Reinhold Publishing Co., New York, New York, July 1961, p. 107.

f. Sulfrian, G. F., "A Facility for Cryogenic Testing and Research," <u>Test Engineering & Management</u>, Vol. 12, No. 5, Mattingly Publishing Co., Inc., Oakhurst, Illinois, 1960, pp. 1-14.

g. <u>Cryogenic Information Report</u>, Vol. 3, No. 5, Technical Economics Associates, Wauconda, Illinois, August 1965, Sections I-IV.

3. Pamphlets and brochures

a. "Hofman Low Temperature Equipment," Hofman Laboratories, Inc., Hillside, New Jersey, undated, pp. 1-63.

b. "Oxygen," No. 5881, Liquid Carbonic Division of General Dynamics, Chicago, Illinois, 1960, pp. 1-14.

c. "Precautions and Safe Practices for Handling Liquefied Atmospheric Gases," F-9888-H, Linde Division of Union Carbide Corp., New York, New York, 1966, (7 pages).

d. "The Revolutionary Linde LC-3 Liquid Oxygen Container," F-1258B, Linde Division of Union Carbide Corp., New York, New York, 1967, (4 pages).

D. Audiovisual aids

1. Displays

   a. Exhibit of metallic material samples used with cryogenic liquids at the Center.

   b. Exhibit of nonmetallic materials used with some of the cryogenic fluids at the Center

2. Film — "Liquid Oxygen — Safe Handling and Storage," (MN-8364B, U.S. Navy, unclassified)

3. Graphics displays

   a. S-67-20407 "Aerial View of Manned Spacecraft Center" (See appendix B.)
   b. S-67-35693 "Gaseous Content of Dry Air" (See appendix B.)
   c. S-67-35694 "Air" (See appendix B.)

4. Opaque projection materials

   a. "Location and Types of Cryogenic Liquids Used at the Manned Spacecraft Center" (appendix E)

   b. "View of Nonmetallic Materials Used with Cryogenic Liquids" (S-67-36439)

   c. "View of Metallic Materials Used with Cryogenic Liquids" (S-67-36449)

5. Transparencies

   a. S-67-457 "Objectives"
   b. S-67-96 "Cryogenics"
   c. S-67-4616 "Comparative Low Temperature Chart" (See appendix B.)
   d. S-67-462 "Cryogenic Thermometer"
   e. S-67-152 Untitled (Example of a system)
   f. S-67-88 "Air" (See appendix B.)
   g. S-67-98 "Liquid Oxygen Properties and Characteristics"
   h. S-67-90 "Oxygen Safety and Handling"
   i. S-67-4355 "LOX — Major Hazards"
   j. S-67-4350 "LOX — In Case of Accident"
   k. S-67-156 "Leave an Opening to Prevent Excessive Pressure"

E. Suggested lesson plan guide and accompanying suggestions for the instructor — appendix E

F. Session quiz and related answer sheet — appendix E

G. Selected support materials

1. Opaque projection materials
2. Transparencies
3. "Some Cryogenic Highlights"
4. "Some General Cryogenic Safety Precautions"

Suggested Curriculum Outline

for

Session 6

LIQUID NITROGEN AND RELATED ASPECTS

A. Objectives

1. To gain an awareness of the general properties and characteristics of liquid nitrogen (LN_2)
2. To become familiar with the hazards, safety procedures, and special protective clothing associated with handling LN_2
3. To demonstrate the effects of LN_2 on various materials
4. To become aware of the methods of manufacture and production of LN_2 and LOX

B. Suggested format of instruction

1. Overview of the production of LN_2 and LOX
2. Effects that LN_2 has on various materials
3. Characteristics and properties of LN_2
4. Hazards and safety measures
5. Materials and equipment used with LN_2
6. Storage of LN_2
7. Spills, leaks, and decontamination
8. Typical LN_2 system associated with the Center
9. System safety
10. Session assessment
11. Summary and distribution of handout materials

C. Reference material and printed matter

1. Texts and manuals — Manned Spacecraft Center Safety Manual (MSCM 1700), Part 5, Subpart 8, Liquid Nitrogen.

2. Periodicals

   a. "While Handling Liquid Nitrogen — Look Out!," Technical Sales Department, Liquid Carbonic Division of General Dynamics Corp., reprinted from Quick Frozen Foods Magazine, November 1965.

   b. Casey, J. M., "NASA's SESL: World's Largest Space Simulation Lab — Part I," Cryogenic Engineering News, Vol. 1, No. 13, November 1966, pp. 26-32.

   c. Casey, J. M., "NASA's SESL: World's Largest Space Simulation Lab — Part II," Cryogenic Engineering News, Vol. 1, No. 14, December 1966, pp. 30-35.

3. Bulletins and pamphlets

   a. "Handling and Storage of Liquid Propellants," Office of the Director of Defense Research and Engineering, Washington, D.C., undated, pp. 1-9.

   b. "Nitrogen," No. 5896, Liquid Carbonic Division of General Dynamics, Chicago, Illinois, 1966, pp. 1-14.

   c. "Precautions and Safe Practices for Handling Liquefied Atmospheric Gases," F-9888-J, Linde Division of Union Carbide Corp., New York, New York, 1966, pp. 1-7.

   d. "Precautions for the Safe Handling and Storage of Liquid Oxygen and Nitrogen," Technical Data and Process Bulletin, ADE 885A, Air Reduction Co., Inc., New York, New York, 1964, pp. 1-3.

   e. "Technical Data on Liquid Nitrogen," F-109-A, Linde Division of Union Carbide, New York, New York, 1960, pp. 1-20.

4. Catalogs — "Bulk Liquid Customer Stations," Catalog 450, Air Reduction Co., Inc., New York, New York, 1961, pp. 1-6.

D. Audiovisual aids

1. Displays — appropriate equipment items used with LN_2 for cleaning purposes, containers, pipes, fittings, gaskets, valves, pumps, vaporizers, gages, and so forth.

2. Equipment and related materials

   a. Dewar vessels

   b. Protective clothing, such as face shield, gloves, apron, and so forth

c. Rubber tubing and ball, vegetable and/or fruit, lubricant, alcohol, and other materials

3. Films — "Oxygen-Nitrogen Generating Plant," U.S. Navy Film MN 8210 A (unclassified).

4. Opaque projection materials

   a. S-67-36444 "Display of Several 'Dewar Type' Storage Containers"
   b. S-67-20079 "Transferring Liquid Nitrogen"
   c. S-67-17850 "28,000 Gallon LN_2 Storage Tank"
   d. S-67-36437 "Transferring LN_2"

5. Transparencies

   a. S-67-153 "Separation of Industrial and Rare Gases from the Atmosphere"
   b. S-67-157 "Diagram of Air Separation Cycle"
   c. S-67-99 "Liquid Nitrogen Properties and Characteristics"
   d. S-67-90 "Oxygen Safety and Handling" (See appendix E.)
   e. S-67-161 Untitled — Storage Tank with Safety Markings
   f. S-67-159 "Cryogenic Identification Standard for LN_2"
   g. S-67-160 Untitled — LOX and LN_2 Identifications in Use
   h. S-67-158 "Cryogenic Identification Standard for LOX"
   i. S-67-4353 "LN_2 Major Hazards"
   j. S-67-4346 "LN_2 In Case of Accident"

E. Suggested lesson plan guide and accompanying suggestions for the instructor — appendix F

F. Session quiz and related answer sheet — appendix F

G. Selected support materials

1. "LOX-LN_2 Production," poem

2. Opaque projection materials and transparencies

Suggested Curriculum Outline

for

Session 7

LIQUID HYDROGEN AND RELATED ASPECTS

A. Objectives

1. To gain further awareness of general properties and characteristics of LH_2
2. To become familiar with LH_2 hazards and safety measures
3. To become cognizant of proper transfer and storage procedures
4. To understand the role and use of LH_2 at the Center

B. Suggested session coverage

1. Review of the highlights of the preceding session, with emphasis placed on the safety measures discussed
2. Session objectives and general uses of liquid hydrogen
3. General properties and characteristics of LH_2
4. LH_2 hazards
5. Safety measures
6. Transfer and storage
7. Materials used with liquid hydrogen
8. Main storage for LH_2
9. Shipping of liquid hydrogen
10. Liquid hydrogen overview
11. Session assessment

12. Résumé of the session and announcement of topic(s) for the next session

13. Distribution of handout materials

C. Reference material and printed matter

1. Texts and manuals

   a. Manned Spacecraft Center Safety Manual (MSCM 1700), Part 5, Subpart 7.

   b. Scott, Russell B., Cryogenic Engineering, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1966, pp. 41-57.

   c. Vance, R. W. and Duke, W. W. (editors), Applied Cryogenic Engineering, John W. Wiley & Sons, New York, New York, 1962, pp. 180-186.

2. Periodicals and reports

   a. Chelton, D. B., "Safety in the Use of Liquid Hydrogen," reprinted from Technology and Uses of Liquid Hydrogen, Pergamon Press, Oxford, Great Britain, 1964, pp. 359-376.

   b. Cryogenic Information Report, Vol. 3, No. 5, Technical Economic Associates, Wauconda, Illinois, August 1965, Section I - 20 and 26, Section III - 1, 2, 3, and 5, and Section IV - 8.

   c. "Recommended Materials and Practices for Use with Cryogenic Propellants," Aerospace Information Report, AIR 839, Society of Automotive Engineers, Inc., January 1965, pp. 3-29.

   d. "Safety Instruction and Safety Guide for Handling Gaseous and Liquid Hydrogen at the Boulder Laboratories," Memorandum Report No. CM-4, Boulder Laboratories, National Bureau of Standards, U.S. Department of Commerce, Boulder, Colorado, January 1960, pp. 1-21.

3. Pamphlets and brochures

   a. "Precautions and Safe Practices for Handling Liquid Hydrogen," F-9914-B, Linde Division of Union Carbide Corp., 1960, pp. 1-8.

D. Audiovisual aids

1. Exhibits

   a. Mannequin

   b. Appropriate cryogenic suit materials for placement on mannequin

2. Graphics display — S-67-20407 "Aerial View of the Manned Spacecraft Center"

3. Opaque projection materials — S-67-17861 "Special Hazards Vehicle"

4. Slides — "Liquid Hydrogen"

5. Transparencies

   a. S-67-574 "LH_2 Characteristics"
   b. S-67-572 "LH_2 Characteristics (cont'd)"
   c. S-67-577 "LH_2 First-Aid Notice"
   d. S-67-578 "Potential in Handling LH_2 . . ."
   e. S-67-4354 "LH_2 Major Hazards"
   f. S-67-4347 "LH_2 In Case of Accident"
   g. S-67-155 "Hydrogen — Safety and Handling"
   h. S-67-4969 "Typical Transfer Operation (Rigid Transfer Tube)"
   i. S-67-4349 "Typical Transfer Operation (Flexible Transfer Tube)"
   j. S-67-576 "Materials Utilized with LH_2"
   k. S-67-569 "Metals Suitable for Use with LH_2"
   l. S-67-573 "Nonmetals Suitable for Use with LH_2"

E. Suggested lesson plan and accompanying suggestions for the instructor — appendix G

F. Session quiz and related answer sheet — appendix G

G. Selected support materials

1. Script for slide presentation entitled "Liquid Hydrogen"

2. Opaque projection materials and transparencies

Suggested Curriculum Outline

for

Session 8

LIQUID HELIUM AND RELATED ASPECTS

A. Objectives

1. To familiarize course participants with the unusual properties of liquid helium in comparison with other cryogenic liquids

2. To further acquaint class members with safety precautions pertaining to liquid helium (LHe)

3. To study the utilization and potential of helium at this Center and related areas such as government and industry

B. Suggested outline of instruction

1. Review of preceding session, including its relation to this session

2. Growth and development of helium as a cryogenic liquid

3. Physical characteristics and properties of liquid helium, including its unusual attributes

4. Further overview of liquid helium aspects

5. Safety measures and precautions

6. Liquid helium specifications and utilization at the Center and elsewhere

7. Cryogenic system design

8. Session assessment

9. Summary and distribution of handout materials

C. Reference materials and printed matter

1. Periodicals and reports

   a. Garvin, Leo, "Helium — Today and Tomorrow: II. Liquid Helium," Cryogenic Technology, Vol. 2, No. 3, Cryogenic Technology

Publications, Bel Air, Los Angeles, California, September/October 1966, pp. 102-104.

b. Bickart, C., and Visivanathan, "A Glass/Metal Liquid Helium Dewar," Cryogenic Technology, Vol. 3, No. 3, Cryogenic Technology Publications, Inc., Bel Air, Los Angeles, California, May/June 1967, pp. 96-98.

2. Pamphlets and brochures

a. "Airco Helium," Pamphlet ADG 2190, Air Reduction Co., Inc., New York, New York, 1966, pp. 1-6.

b. "Liquid Helium," ADC 877C, Air Reduction Co., Inc., New York, New York, 1964, pp. 1-4.

c. "Liquid Helium Containers and Handling Practices," Bulletin No. 2448, Air Reduction Co., Inc., New York, New York, 1966, pp. 1-19.

d. "Precautions and Safe Practices for Handling Liquid Helium," Booklet F-11-205, Linde Division of Union Carbide, Corp., New York, New York, 1962, pp. 1-19.

e. "Procedures for Handling Liquid Helium," F-2647, Linde Division of Union Carbide, New York, New York, undated, pp. 1-8.

D. Audiovisual aids

1. Film clip — untitled silent film clip on oscillations and liquid helium

2. Slides — "Liquid Helium"

3. Transparencies

a.	S-67-151	"Boiling Point of Cryogens" (See appendix E.)
b.	S-67-4614	"Helium Specification"
c.	S-67-456	"LHe Applications"
d.	S-67-460	"LHe Safety Precautions"
e.	S-67-461	"LHe Safety Precautions"
f.	S-67-450	"LHe Safety Precautions"
g.	S-67-455	"LHe Safety Precautions"
h.	S-67-459	"LHe Safety Precautions"
i.	S-67-451	"LHe Safety Precautions"
j.	S-67-453	"LHe Safety Precautions"
k.	S-67-91	"Superconductivity"
l.	S-67-89	"Superconductors"
m.	S-67-95	"Superconductors"

E. Suggested lesson plan and accompanying suggestions for the instructor — appendix H

F. Session quiz and related answer sheet — appendix H

G. Selected support materials

1. Script for slide presentation entitled "Liquid Helium"

2. Transparencies

Suggested Curriculum Outline

for

Session 9

CARBON DIOXIDE AND THE RARE GASES EXCLUDING HELIUM

A. Objectives

1. To become familiar with the characteristics and properties of carbon dioxide (CO_2) and the rare gases, such as argon (A), krypton (Kr), neon (Ne), and xenon (Xe)

2. To become further aware of how carbon dioxide and the rare gases are produced and of their respective uses, especially at this Center

3. To become more knowledgeable about hazards and safety measures which pertain to CO_2, A, Kr, Ne, and Xe

B. Suggested outline of instruction

1. Announcements and review of the preceding session
2. Objectives for this session
3. Overview of the rare gases
4. Characteristics and properties of rare gases
5. Production of rare gases
6. Hazards and safety measures
7. Uses of rare gases, especially at this Center
8. Carbon dioxide
9. Session assessment
10. Summary and distribution of handout materials

C. Reference material and printed matter

1. Texts and manuals — Handbook on Compressed Gases, American Gas Association, Reinhold Publishing Corp., New York, New York, 1966, pp. 45-57, 55-61, 147-149.

2. Pamphlets and brochures

    a. "Argon," Liquid Carbonic Division of General Dynamics, Form No. 5897R-2, Chicago, Illinois, 1964, pp. 1-13.

    b. "Carbon Dioxide," No. AD 1125-260, Olin Mathieson Chemicals Division; Olin Mathieson Chemical Corp., Baltimore, Maryland, 1962, pp. 1-13.

    c. "CO_2," No. 15M-5382, Pure Carbonic Co., a Division of Air Reduction Co., Inc., New York, New York, December 1959, pp. 1-21.

    d. "High Purity Gases," No. F-1002C, Linde Division of Union Carbide Corp., New York, New York, undated, pp. 1-15.

    e. "High Purity Rare Gases," No. F-1545B, Linde Division of Union Carbide Corp., New York, New York, undated, pp. 1-23.

    f. "Precautions and Safe Practices for Handling Liquefied Atmospheric Gases," No. F-9888-H, Linde Division of Union Carbide Corp., New York, New York, 1965, p. 7.

    g. "Rare Gases," No. 20M-9087, Air Reduction Co., Inc., New York, New York, 1964, pp. 1-28.

    h. "Rare Gases and Mixtures," No. F-3964D, Linde Division of Union Carbide Corp., New York, New York, undated, pp. 1-4.

    i. "What is CO_2?" No. 5983-R, Liquid Carbonic Division of General Dynamics, Chicago, Illinois, February 1964, pp. 1-30.

3. Catalogs — "Industrial Gases and Cryogenic Fluids," Catalog No. 300, Air Reduction Co., Inc., New York, New York, December 1963, pp. 16-28.

D. Audiovisual aids

1. Graphics displays — S-67-20407 "Aerial View of the Manned Spacecraft Center"

2. Opaque projection materials

    a. S-67-17861 "Special Hazards Vehicle"
    b. S-67-35693 "Gaseous Content of Dry Air"

3. Transparencies

    a. S-67-4615 "Here's How the Boiling Points of Cryogens Compare"
    b. S-67-4753 "Liquid to Gas Expansion Ratios"

c. S-67-4752 "Approximate Liquid to Water Density Ratios"
d. S-67-153 "Separation of Industrial and Rare Gases from the Atmosphere" (See appendix F.)
e. S-67-570 "CO_2 Physical Constants"
f. S-67-571 "CO_2 Physical Constants (cont'd)"
g. S-67-579 "L. P. Liquid CO_2 System"
h. S-67-575 "Solid CO_2"
i. S-67-4750 "Bulk L. P. CO_2 Liquid Container Handling Precautions"
j. S-67-4751 "Bulk L. P. CO_2 Liquid Containers"

E. Suggested lesson-plan guide accompanied by suggestions for the instructor(s) — appendix I

F. Session quiz and related answer sheet — appendix I

G. Selected support materials

1. "Versatile Carbon Dioxide"

2. Opaque projection materials

3. Transparencies

Suggested Curriculum Plan

for

Session 10

NEW DEVELOPMENTS, RÉSUMÉ, AND ASSESSMENT

A. Objectives

1. To discuss current and future developments in the compressed gas and cryogenic liquid fields

2. To review the course objectives and summarize safety and related aspects of compressed gases and cryogenic liquids

3. To appraise the course from both content and instructional points of view

4. To present course completion certificates and have a group photograph taken (optional)

B. Suggested outline of instruction

1. Review of the highlights of the preceding session and the objectives for this session

2. Development and trends in the compressed gas and cryogenic fields within the Center, as well as within industrial and governmental organizations

3. Review of the goals of the course and the vital role played by safety in both the compressed gas and cryogenic fields

4. Assessment of the content and instruction of the course

5. Presentation of certificates and activities related thereto

C. Reference material and printed matter

1. Texts and manuals

    a. Manned Spacecraft Center Safety Manual (MSCM 1700).

    b. Zabetakis, Michael G., Safety with Cryogenic Fluids, Plenum Press, New York, New York, 1967, pp. 1-156.

2. Periodicals and brochures

a. Englehardt, S. L., "Supercold: Hottest Thing in Surgery," Reader's Digest, Vol. 91, No. 541, Reader's Digest Association, Inc., Pleasantville, New York, May 1967, pp. 131-135.

b. Logan, Edwin M., and Kitts, William T., "A Safety Course in Compressed Gases and Cryogenic Liquids," Cryogenic Technology, Vol. 3, No. 3, Cryogenic Technology Publications, Inc., Bel Air, Los Angeles, California, May/June 1967, p. 89.

c. Logan, Edwin M. and Kitts, William T., "Industry Joins MSC in Gas-Cryogen Safety Course," Cryogenics Engineering News, Vol. 2, No. 6, June 1967, pp. 32-33.

d. Parker, Jerald D., "Basics of Liquefaction," Reprinted from Oil and Gas Equipment, Vol. 13, No. 4, An Oil and Gas Journal Publication, Tulsa, Oklahoma, February 1967, p. 6.

e. Parker, Jerald D., "Storage and Bulk Transport of Cryogens," Reprinted from Oil and Gas Equipment, An Oil and Gas Journal Publication, Tulsa, Oklahoma, March 1967, pp. 1-2.

f. Parker, Jerald D., "How to Select Pipes, Valves, and Pumps for Cryogen Transfer," Reprinted from Oil and Gas Equipment, An Oil and Gas Journal Publication, Tulsa, Oklahoma, April 1967, pp. 1-3.

g. Parker, Jerald D., "Here's How to Select the Best Insulation for Cryogenic Service," Reprinted from Oil and Gas Equipment, An Oil and Gas Journal Publication, Tulsa, Oklahoma, April 1967, pp. 1-3.

h. Parker, Jerald D., "How Materials Behave at Cryogenic Temperatures," Reprinted from Oil and Gas Equipment, An Oil and Gas Journal Publication, Tulsa, Oklahoma, June 1967, pp. 1-3.

i. "Recreation," Time, Vol. 89, No. 24, June 16, 1967, Time, Inc., New York, New York, p. 53.

D. Audiovisual aids

1. Opaque projection materials

a. S-67-60581 (Untitled) Typical Portable Ventilator

b. S-67-60582 (Untitled) A PLSS — Portable Life Support System

c. S-67-42417 (Untitled) Example of Course Completion Certificate

2. Transparencies — S-67-452 "Current Cryogenic Research"

E. Suggested lesson plan guide and accompanying suggestions for the instructor — appendix J

F. Test — No specific quiz for this session, although the course pretest could be used as a course posttest

G. Selected support materials

1. Transparencies

2. Opaque projection materials

APPENDIXES

Introduction

The following appendixes to the curriculum present supplementary information considered important to the users of this manual.

Appendixes A to J correspond to sessions 1 to 10. Appendix A for example, pertains to session 1. Each appendix includes the following for a given session:

1. A suggested lesson plan guide and accompanying suggestions for the instructor

2. A quiz and related answer sheet

3. Selected support materials

Appendix K, a master sensory materials list, includes equipment, sensory materials of instruction, and related curriculum support materials.

Appendix L is composed of several instructional techniques which may prove helpful to the users of this curriculum guide.

Appendix M provides a quick reference to many of the basic items required for the classroom for presentation of this course. Equipment, aids, and accessories are included.

APPENDIX A

1. A suggested lesson plan guide and accompanying suggestion for the instructor(s)

2. A quiz and related answer sheet

3. Selected support materials

Lesson Plan

for

Session 1

COURSE OVERVIEW AND INTRODUCTION

Estimated Time[1]	Item(s)
	1.0 Course introduction
	1.1 Introduce the instructor(s).
0020	1.2 Present title of the course (chalkboard).
	2.0 Registration of the class participants
	2.1 Distribute and have each class participant complete a Data Form.
	2.2 Distribute course folders, programs, and "tent cards" during completion of Data Forms by course participants.
	2.3 Collect completed forms.
	2.4 Request course enrollees, upon completing "tent cards," to place cards so that they can be viewed by others, including the instructor(s).
	2.5 Have each class participant introduce himself by name, organization (Center/contractor), and statement of a few words about his present position and himself.
0035	2.6 Present policies concerning smoking, restrooms, class breaks, vending machines, and so forth.
	3.0 The need for this course
	3.1 Discuss the magnitude and scope of the course, pointing out that the field of compressed gases and cryogenics is increasing in magnitude

[1]The time is expressed in minutes up to 1 hour (0100) and then as 1 hour plus a designated number of minutes up to 2 hours (0200).

Estimated Time | Item(s)

and scope at this Center as new developments related to space exploration continue to be made in both fields.

3.2 Relate that one injury, which could have been extremely serious, occurred at this Center in 1966, and that it is hoped that the presentation of this course will prevent injuries of a comparable nature happening to others in the future.

4.0 Course coverage, presentation length, and evaluation

4.1 Present the course and session objectives.

a. General

(1) To stress safety in the handling of compressed gases and cryogenic liquids at MSC

(2) To become familiar with the characteristics and properties of compressed gases and cryogenic liquids used at the Center

(3) To become acquainted with the methods used to manufacture and produce compressed gases and cryogens, especially from a safety point of view

b. Session

(1) To register course participants and provide orientation to the course and its topics

(2) To administer a pretest to determine the appropriate class level based on knowledge of subject matter

(3) To disseminate textual, reference, and handout materials

4.2 Use transparency (NASA S-67-94) to cover three basic areas — composition of atmosphere, compressed gases, and cryogenics. These topics have been divided into 10 subtopics for presentation purposes. Display transparency (S-67-4352) and discuss each subtopic.

Estimated Time	Item(s)
	4.3 Present overview of schedule of classes by time and date.
0050	4.4 Explain need for critical evaluation of course. (Point out that "C&I evaluation sheets" will be distributed at the end of this session.)
	<u>5.0 General methods of presentation</u>
0055	5.1 Use transparency (S-67-92) to show various types of methods and techniques that will be used to present this course. Mention also the utilization of special reports. (The "team teaching" approach is optional.)
	<u>6.0 Audience design</u>
0100	6.1 State that this course has been designed primarily for engineering and laboratory technicians who are either MSC or contractor support personnel and who will be working with or in the vicinity of compressed gases and cryogenic fluids. Some phases of the course may serve as a review for some, while the data presented will be new to others.
0110	C L A S S B R E A K
	<u>7.0 Pretest (and review)</u>
	7.1 Furnish pretest instructions to the class and administer the test. Explain the purpose of the test.
	7.2 After the class participants complete the quiz, collect the quiz and review each test item with the class.
0145	7.3 Tell the class participants that an objective analysis of the pretest items will be made and presented at the beginning of the next session.
	<u>8.0 Distribution of materials</u>
	8.1 Distribute course evaluation forms to the class. Request each class participant to make daily

Estimated Time	Item(s)
	notations on the blank pages affixed to the form so that his final assessment will be as complete as possible.
	8.2 By Session 10, class participants are requested to submit two quiz items for each Session from 2 to 9. Items, such as completion, multiple choice, and matching, are preferred. (True and false quiz items should not be included.) (Item 8.2 is optional.)
	8.3 Show the class participants a sample display of printed texts, periodicals, and related materials to which they will be exposed during the course.
	8.4 Assign class reports for Sessions 2 to 6 (optional).
	8.5 Summarize the session by covering the major objectives completed and inviting questions or comments from the class.
	8.6 Distribute copies of Manned Spacecraft Center Safety Manual and related safety materials.
0200	8.7 State the name of the topic for the next session (and place it on the chalkboard).

Notations to the Instructor

1. Arrange a visual display of exhibit reference materials for the class participants prior to class.
2. Insure that tables and/or chairs and an adequate supply of pencils are available for the course participants.
3. Have adequate copies of participant folders, pads, pretests, safety manuals, and course evaluation sheets.
4. Refer to appendix N, "Suggested Classroom Needs."
5. Have the transparencies required available and an overhead transparency projector ready for use.
6. Make appropriate outside reading assignments for class reports to include Sessions 2 through 5. (Optional)
7. Verify parking space arrangements for the guest lecturer and also confirm time, building location, and equipment needs with the guest lecturer. (Optional)

8. During a "dry run," actually perform or simulate the lesson plan on a "step-by-step" basis.

9. When furnishing instructions for the pretest, have the class members place name and date on each quiz page, check each page of the test to insure its presence, and make any corrections or modifications which may be necessary.

10. Review in appendix M the sections on "Using Audiovisual Materials Effectively" and "The Display Board."

11. Check the curriculum for specific handout items to be distributed this session.

12. Each session has been designed for a total of 2 hours. Since this course may start in the morning or the afternoon, the time for each session commences with "0000" hours and ends at "0200," the end of the 2-hour period. The time between 0000 and 0200 is expressed in minutes up to 1 hour in time (0100) and then as 1 hour plus a designated number of minutes up to 0200.

13. The estimated time of 0020 may seem long for Section 1.0 of the lesson plan. Experience, unfortunately, has shown that for one reason or another, several class enrollees will invariably be late the first day of class. However, from this session on, commence class promptly at the designated time.

APPENDIX A

Session 1 Pretest

COURSE OVERVIEW AND INTRODUCTION

A. True or False

____ 1. Normally, oxygen can be produced by a variety of processes, but the liquefaction-fractional process is the foremost production method in use today.

____ 2. Liquid nitrogen is used as a coolant and is circulated in the heat sinks or "cold walls" of environmental test chambers to simulate the conditions away from the sun in outer space.

____ 3. Above the critical temperature of 87.8°F, carbon dioxide cannot exist in a liquid state, regardless of pressure.

____ 4. In quality assurance, lot acceptance tests are those analyses performed on the gas in the shipping container or a sample thereof, which is representative of the lot.

____ 5. Since helium exists in the atmosphere as merely one part in 200,000, only a small amount is produced commonly by fractionation, most of it obtained from natural gas deposits.

____ 6. The Center's central gas storage facility, building 380, is operated by the Center's Supply Branch.

____ 7. In the United States, helium deposits are controlled by the Government and the gas must be obtained through the U.S. Bureau of Mines for shipment outside the United States.

____ 8. Because of the smallness of the molecules that compose it and because it is normally absent from the atmosphere in detectable quantities, gaseous helium can be used to good advantage as a tracer gas in leak detection.

____ 9. The only known substance in the universe which remains fluid at temperatures close to absolute zero (-459.6° F), liquid helium has a unique use as a refrigerant for producing extremely low temperatures needed for conducting cryogenic research.

____ 10. When liquid hydrogen tanks are removed from service, the tasks are purged with an inert gas before admitting air, so as to prevent a combustible atmosphere from being formed.

Session 1 Pretest (cont'd)

___ 11. Since it exists as only a trace of air, hydrogen can be more easily obtained in large quantities by electrolysis of water or by cracking hydrocarbon gases, than by separation from the earth's atmosphere.

___ 12. At superatmospheric pressures, primarily in aquatic diving operations, a helium-oxygen mixture is being used as a breathing gas to permit swimmers to remain underwater for sustained periods of time.

___ 13. The rare gases have the unusual ability of becoming electrically conductive at a lower voltage than other gases.

___ 14. Two responsibilities of the MSC Quality Assurance Branch personnel are to witness and verify sample extractions and to monitor the functional operations of laboratories making the analysis.

___ 15. The rare gases are also referred to as "noble" because of their scarcity and inactivity.

___ 16. Rupture disks can be used to eliminate leakage of valuable or toxic gases, or to protect the relief valve from highly corrosive products.

___ 17. A conventional gas cylinder holds its contents in gaseous form at ambient temperatures under high pressure.

___ 18. The pressure regulator used with a compressed gas cylinder is not only a convenience, but also is absolutely necessary for safe utilization in the use of the gas at lower pressures.

___ 19. Pressure in compressed gas cylinders can run up to several thousand pounds per square inch (psig).

___ 20. Liquid hydrogen storage tanks which are vacuum-jacketed and insulated with a noncombustible material, such as Santocel, Perlite, or super insulation, must be properly cleaned to remove all grease and dirt.

B. Completion

__________ 1. The four most commonly used temperature scales are

__________ 2. (1)__________, (2)__________, (3) __________, and

__________ 3. (4)__________.

__________ 4.

__________ 5. The formula for converting Centigrade to Fahrenheit is (5) __________.

__________ 6. The temperature of ice is (6)__________ degrees F.

Session 1 Pretest (cont'd)

__________ 7. The temperature of ice is (7) __________ degrees R.

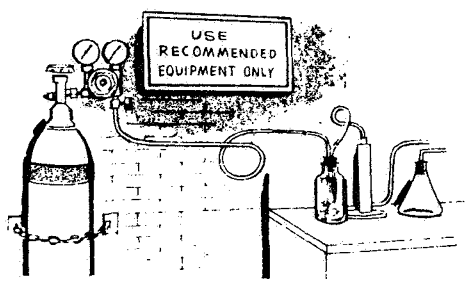
__________ 8. Given -184.44 degrees Centigrade, the equivalent temperature in Fahrenheit is (8) __________ degrees.

C. Pictorial Matching

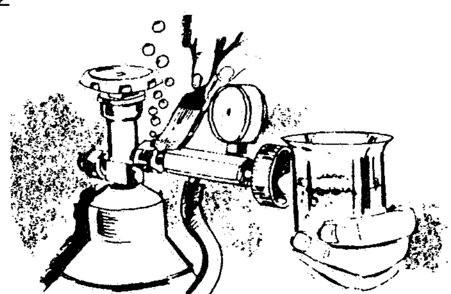
The following four drawings and eight statements pertain to compressed gases. One matching statement is appropriate to each drawing. Place the number representing the appropriate matching statement in the blank preceding the correct corresponding drawing.

Drawing

____ 1



____ 2



____ 3

Statement

1. Prevent chemical burns by using protective clothing — mask, rubber gloves, aprons, and so forth — when handling corrosive gases.

2. Return empty cylinders in good condition. Close valve, replace valve protective cap, and dust caps. Mark or label cylinder "EMPTY" or "MT."

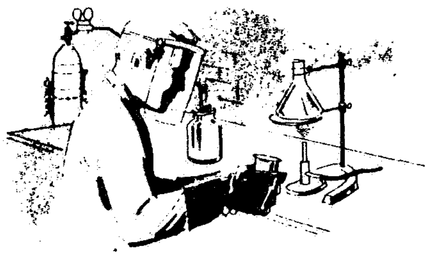
3. Don't drop cylinders. Never drop cylinders or permit them to strike each other violently.

4. Prevent corrosion by using properly constructed equipment and materials to contain gas.

5. Secure cylinders to firm support (wall, stand, and so forth) by means of chain or belt, or place in a cylinder stand.

6. Do not force connection fittings. Make sure connections to cylinders match the valve outlet. Do not interchange various controls on different gases.

Session 1 Pretest (cont'd)



7. Transport correctly by means of a suit hand truck. Never roll a cylinder.

8. Prevent leaks by checking for leaks with soap solution or detectors (never use flame). Contact supplier if leaks occur in cylinder valve.

D. Multiple Choice

___ 1. Cryogenics is the science that deals with the production of ultra-low temperatures and their effect on the properties of matter. These temperatures are usually below:

a. -50° F
b. -100° F
c. -150° F
d. -200° F
e. -250° F

___ 2. Which of the following cryogens have boiling points of below -400° F?

a. Neon
b. Krypton
c. Argon
d. Nitrogen
e. Oxygen

___ 3. The cryogenic identification standard for LN_2 CAUTION safety signs requires 4000-gallon trailers to show the word "caution" in letters __________ inches long.

a. 2
b. 4
c. 8
d. 12
e. 16

___ 4. One of the materials frequently used as a lining for rupture disks is:

a. Platinum
b. Tin
c. Copper
d. Nickel
e. Silver

Session 1 Pretest (cont'd)

___ 5. Among the symbols used for propellant flow is -| | |- which represents:

a. New burst diaphragm
b. Pressure regulator
c. Solenoid valve
d. Electrical flowmeter
e. Pressure gage

___ 6. In a typical vessel pressurization and vent system for liquid control, __________ represents the symbol for a:

a. Hand valve
b. Relief valve
c. Check valve
d. Dome pressure regulator
e. Filter

___ 7. Any high-pressure cylinder damage, such as cuts, dents, arc burns, exposure to fire, or excessive corrosion caused by rough handling, must be removed from service and either reconditioned or scrapped in accordance with requirements explicitly established by the:

a. Compressed Gas Association
b. American Cryogenics Association
c. National Fire Protection Association
d. Interstate Commerce Commission
e. Bureau of Mines

___ 8. When given a preference, commercial pilots normally prefer to fly in the:

a. Ionosphere
b. Atmosphere
c. Stratosphere
d. Exosphere
e. Troposphere

___ 9. Which of the following is <u>not</u> applicable as a safety aspect of the Dewars?

a. Is of relatively fragile construction
b. Is of rugged and sturdy construction
c. Is not equipped with its own relief system
d. Is a container for which handlers can dispense with gloves, face shields, and so forth
e. Is useless for handling liquid helium

Session 1 Pretest (cont'd)

___ 10. If excessive spillage of argon occurs in a confined working area, the procedure to be followed <u>prior</u> to entering the area is as follows:

a. Spray the area with foam or a dry chemical.
b. Enter the area as soon as the door can be opened.
c. Actuate the nearest fire alarm.
d. Spray the area with water.
e. Enter only if equipped with an operating support system.

APPRAISAL OF THE SAFETY COURSE IN INDUSTRIAL GASES AND CRYOGENIC FLUIDS AND ITS INSTRUCTOR(S)

This brief two-part questionnaire has been designed to obtain constructive criticism, as well as your evaluation of this course and its instructors. Your appraisal, to be effective, should be as objective as possible. To enhance this objectivity, please do not sign your name.

Appraisal of Instructors

A. Instructor personal traits. Various traits characteristic of most instructors have been enumerated below. Please indicate by a check (✓) in the appropriate column, the degree to which your instructor possesses each of these characteristics.

TRAIT	DEGREE					
	Unknown	Excellent	Good	Average	Poor	Very Poor
1. Adaptability						
2. Personal Appearance						
3. Interest in Course						
4. Interest in Class						
5. Accuracy and Thoroughness						
6. Consideration of Class						
7. Cooperation						
8. Dependability						
9. Enthusiasm						
10. Fluency						
11. Forcefulness						
12. Judgment						
13. Personal Integrity						
14. Industry						
15. Leadership						
16. Magnetism						
17. Openmindedness						
18. Patience						
19. Originality						
20. Promptness						
21. Scholarship						
22. Refinement						
23. Self-Control						
24. Professional						
25. Other (please specify)						

Appraisal of Instructors (cont'd)

B. In comparison with other instructors you have had, would you

____ Particularly desire to have this instructor?
____ Prefer him to most?
____ Be pleased to have him?
____ Be satisfied to have him?
____ Prefer not to have him?

C. Instructor Classroom Traits. Please check (✓) "yes" or "no" as appropriate.

Yes	No		Item
		1.	Did the class area have good lighting, proper heat, and adequate ventilation?
		2.	Does the instructor know the names of the class participants?
		3.	Is the instructor punctual, and does he expect punctuality?
		4.	Does the instructor address the class effectively; that is, does he talk to everyone, including those farthest removed from him?
		5.	Does the instructor make his points clear by using words which can be understood?
		6.	Was it obvious that the instructor prepared his lesson in a satisfactory manner before class?
		7.	Does the instructor keep his class orderly at all times?
		8.	Does the instructor keep the class constructively occupied, thereby utilizing class time well?
		9.	Was the instructor human, yet dignified?
		10.	Were teaching aids prepared before class time?
		11.	Was good use obtained from the teaching aids?
		12.	Were practical applications stressed?
		13.	Does each class member know what is to be accomplished each period?

Appraisal of Instructors (cont'd)

Yes	or No		Item
		14.	Is each session summarized before trainees are dismissed at the end of each period?
		15.	Is appropriate use made of test results?

D. Please use this space for additional comments on the instructor(s).

Course Content

1. Please list, in order of preference, the number representing each of the three most valuable major sessions. Also state why you ranked each choice as you did. (A complete list of these topics is found in the footnote[2] below.)

2. Please list the number of each of the three topics you found to be the least valuable and tell why.

3. Should more time be devoted to lectures? If so, how much?

4. Should more time be devoted to demonstrations?

5. What is your reaction to using the MSC Safety Manual as the basic text?

6. What is your reaction to various periodicals that have been used during this course? To reports given from some of these periodicals?

---

[2]Sessions: 1. Course Overview and Introduction; 2. The Atmosphere and Quality Assurance; 3. Handling Compressed Gases; 4. Compressed Gases; 5. Cryogenics and Liquid Oxygen; 6. Liquid Nitrogen; 7. Liquid Hydrogen; 8. Liquid Helium; 9. Carbon Dioxide and the Rare Gases; 10. New Developments, Résumé, and Assessment.

Course Content (cont'd)

7. Do you think that what you have learned in this course will enable you to do a more effective job in your work? Why?

8. What is your reaction to some of the films borrowed from the armed services and industry for use in this class?

9. Do you think that this course:

___ Is one of the best courses you have ever had?
___ Is one of the better courses that you have had?
___ Is average?
___ Is one of the poorer courses that you have had?
___ Is one of the few unsatisfactory courses that you have had?

10. Based on your knowledge of this Center, how would you recommend this course to others who have never had it?

___ Particularly recommend that the course be taken
___ Recommend that a comparable course be taken
___ Take this course only if required

11. What is your reaction to the system design presently required in the course and its value to you?

12. Do you consider mornings a desirable time to pursue course sessions? Why?

13. What suggestions do you have for improving this course?

14. Please use this space for additional comments.

REGISTRATION DATA SHEET

1. Name ____

2. Contractor/MSC organization ____________________________

   Building ____________________ Room ____________________

3. Position held, such as engineer, technician, operator, and so forth.

   ____

4. Brief description of position duties: ____________________

   ____

   ____

5. List technical/professional societies related to cryogenics and industrial gases with which you have been affiliated. (For example, Cryogenics Society of America, Compressed Gas Association, and so forth): ____________

   ____

   ____

6. Previous courses taken in cryogenics, industrial gases, and related fields (include year taken): ____________________

   ____

   ____

7. Do you have a need for an MSC Safety Manual? /__/Yes /__/No

8. If your answer to item 7 is yes, how many persons, other than yourself, would use it? ____________________

9. Where would the manual be located? building ____________________

   room ____________________

10. From a safety point of view, will your present position require the knowledge of cryogenics and/or industrial gases? /__/Yes /__/No

    How? ____________________

    ____

NASA-S-67-4352

MAJOR TOPICS

1. COURSE OVERVIEW AND INTRODUCTION
2. THE ATMOSPHERE AND QUALITY ASSURANCE
3. HANDLING COMPRESSED GASES
4. COMPRESSED GASES AND RELATED ASPECTS
5. CRYOGENICS AND LIQUID OXYGEN
6. LIQUID NITROGEN AND RELATED ASPECTS
7. LIQUID HYDROGEN AND RELATED ASPECTS
8. LIQUID HELIUM AND RELATED ASPECTS
9. CARBON DIOXIDE AND THE RARE GASES
10. NEW DEVELOPMENTS, RESUME, AND ASSESSMENT

NASA-S-67-4129 JUNE

COURSE COVERAGE

- COMPOSITION OF THE ATMOSPHERE
- COMPRESSED GASES
- CRYOGENICS

NASA-S-67-4130 JUNE

SOME INSTRUCTIONAL TECHNIQUES & METHODS

- LECTURES, DISCUSSIONS, AND DEMONSTRATIONS
- AUDIOVISUAL AIDS INCLUDING FILMS, CHARTS, CHALKBOARD, EXHIBITS, AND TRANSPARENCIES
- PRINTED MATERIALS--INCLUDING TEXTUAL, PERIODICAL, AND HANDOUT ITEMS
- SELF-TESTS

APPENDIX B

1. Suggested lesson plan guide accompanied by notations to the instructor(s)

2. Suggested session quiz and related answer sheet

3. Selected support materials, including an overview of "The Atmosphere and Atmospheric Layers," graphics displays, and transparencies

Suggested Lesson Plan

for

Session 2

THE ATMOSPHERE

AND

THE ROLE OF QUALITY ASSURANCE IN THE HANDLING OF COMPRESSED GASES

Estimated Time	Item(s)
	1.0 Review session introduction
	1.1 Review highlights of the preceding session, stating that it was one of orientation with emphasis on pretest.
	1.2 Discuss the analysis of pretest results which appears on the chalkboard.
	1.3 State the objectives of this session which have been placed on the chalkboard. a. To become more familiar with the four different temperature scales in use b. To review the composition of the air and atmosphere elements which pertain to the Center c. To concentrate on the important role which quality assurance plays in the handling of compressed gases d. To use this session as a springboard to both compressed gases and cryogenic liquids
0010	1.4 Display a copy of the Glossary by holding it before the class. (Mention that it will be distributed as a handout item later in the session.)

Estimated Time	Item(s)
	2.0 Temperature and temperature scales
	2.1 Using transparency S-67-4616, discuss four temperature scales — Centigrade, Fahrenheit, Kelvin, and Rankine — including appropriate comparative conversion relationships.
	2.2 Give the class participants several problems to work at their seats wherein one temperature scale is converted to another.
0025	2.3 Project transparencies S-67-97 and S-67-4351, which depict atmospheric conditions at higher altitudes, such as temperature, pressure, and specific weight at different altitudes.
	3.0 Composition of air
	3.1 After defining the term "atmosphere," project transparency S-67-88 and quickly cover aspects pertaining to the composition of the air.
	3.2 Show chart S-67-35693, which shows the major gaseous contents of air.
0035	3.3 Have different class members briefly discuss items, such as the following, which pertain to the atmosphere: the gaseous contents, water vapor, types of particles, weight, pressure, air motion, resistance, and so forth.
	4.0 Atmospheric layers
	4.1 Exhibit chart S-67-35694, which shows different atmospheric layers.
	4.2 Explain the salient aspects of each of the four layers: troposphere, stratosphere, ionosphere, and exosphere.
0040	4.3 Recapitulate the highlights of the atmosphere and atmospheric layers. (Mention the provision of handouts at the end of this session.)

Estimated Time	Item(s)
	5.0 Atmospheric elements with which the Center is particularly concerned
	5.1 Project transparency S-67-87 and discuss where each of the following is found at the Center and where each is used: nitrogen, carbon dioxide, hydrogen, freon, helium, and argon.
0045	5.2 Ask the class participants to furnish the names, the locations, and the uses of other gaseous elements at the Center. Disucss each class distribution briefly.
	6.0 Atmospheric elements and related Center projects
	6.1 Present chart S-67-35692, which depicts areas of the atmosphere where manned space flight orbits have been and will be conducted: the Mercury suborbital and orbital flights and the Gemini and the Apollo flights.
0055	6.2 Develop an understanding with the class members of the importance of atmospheric elements to the manned space flight programs.
0105	C L A S S B R E A K
	7.0 Quality Assurance
	7.1 Introduce the guest lecturer from Quality Assurance. (Have chart S-67-20407, an aerial view of the Center, available for facility identification purposes.)
	7.2 Have the guest lecturer discuss the following: a. The interface of quality assurance with safety, supply, transportation, and so forth b. The role of the vendor as concerns his contractual requirements with the Center, his processing, and his transportation requirements

Estimated Time	Item(s)
	c. On-site procurement, including receiving inspection, documentation, and so forth
	d. On-site storage involving the following:
	(1) Bonded storage of certified lots of full containers
	(2) Empty containers
	(3) Transportation and shipping
	e. Facility use involving the following:
	(1) Procurement and storage
	(2) Interface with proven and, as appropriate, backup systems
	(3) Return of empty cylinders
	(4) Lot sampling
0145	7.3 Have the guest lecturer summarize his remarks and hold a question and answer session.
	8.0 Assessment
	8.1 Administer the quiz.
0155	8.2 Discuss the quiz items.
	9.0 Summary and distribution of handout materials
	9.1 Summarize the session and announce the topic(s) for the next session.
0200	9.2 Distribute the handout items.

Notations to the Instructor

1. Before class, place the analysis of the pretest and the objectives for this session on the chalkboards. Also review appendix M, "The Chalkboard."

2. Prior to class, arrange for distribution of the following to the class: the comparative conversion temperature scales, the material dealing with the atmosphere and atmospheric layers, the glossary, and so forth.

3. Assure that "pointer" and "flip-chart" stands are available for the chart displays.

4. Have the transparency of the atmospheric chart and the overhead transparency projector ready for class use.

5. The "setup" time for the guest lecturer may take 10 minutes. Therefore, every effort should be made to set up, before the class commences after the class break, so as to use time to optimum advantage.

6. Prepare for distribution of the handout items for this session.

7. Although the term "compressed gas" is generally understood, in this course a compressed gas is a gaseous fluid stored in a container which has a pressure gage reading greater than 14.7 psig at sea level (S-67-4613).

APPENDIX B

Suggested Session 2 Quiz

THE ATMOSPHERE

and

THE ROLE OF QUALITY ASSURANCE IN HANDLING COMPRESSED GASES

A. Completion

__________ 1. The study, the development, and the improvement of extremely low-temperature processes, techniques, and equipment is known as (1)__________.

__________ 2. The atmosphere is divided into four layers. The layer between the troposphere and the ionosphere is the (2)__________.

__________ 3. Of the four layers of atmosphere, pilots prefer to fly in the (3)__________ layer to keep above the thunderstorms and snow.

__________ 4. The uppermost layer of atmosphere commences approximately 300 miles above the earth and is known as the (4)__________.

__________ 5. The one gas which constitutes most of the air is (5)__________.

__________ 6. One of the responsibilities of the MSC (6)__________ __________ Branch is to witness and verify gas sample extractions.

B. Multiple Choice

___ 1. Oxygen constitutes approximately what percentage of air?

a. 1 percent
b. 21 percent
c. 41 percent
d. 61 percent
e. 81 percent

___ 2. Which of the following is not a rare gas?

a. Argon
b. Neon
c. Krypton
d. Nitrogen
e. Xenon

Suggested Session 2 Quiz (cont'd)

___ 3. At sea level, air pressure exerts approximately how many pounds per square inch?

a. 7.7
b. 14.7
c. 21.7
d. 28.7
e. 35.7

___ 4. Which of the following does not contribute to the movement of air?

a. The sun causes air to move or expand by heating it.
b. Air moves around the earth because of the motion of the earth.
c. Air is moved by the gravitational attraction of the moon and sun, and tides result.
d. Air motion results from the vibration, or the constant motion, of gaseous molecules in the air.
e. Movements of large bodies of water, such as oceans, seas, and rivers, cause air motion.

___ 5. Which of the following is not considered a solid particle in the air?

a. Dust
b. Salt
c. Pollen
d. Microbes
e. Compressed gas

C. True and False

___ 1. A written analysis of the gas sample of each vendor's lot acceptance tests is received by quality assurance. This analysis must be retained for user reference purposes.

___ 2. It is the support contractor's responsibility and function to monitor the operations of laboratories making sample analysis of compressed gases.

___ 3. The atmosphere is composed of a mixture of gases which normally cannot be seen.

Session 2 Quiz Answers

A. Completion

1. Cryogenics
2. Stratosphere
3. Stratosphere
4. Exosphere
5. Nitrogen
6. Quality Assurance

B. Multiple Choice

1. b
2. d
3. b
4. e
5. e

C. True and False

1. False
2. False
3. True

APPENDIX B

THE ATMOSPHERE AND ATMOSPHERIC LAYERS

THE ATMOSPHERE

Overview. Air which surrounds the earth, just above the land and sea, is known as atmosphere. The atmosphere is comprised of a mixture of gases which cannot be seen. Water, in the form of vapor, or separated particles too small to see, is mixed with these gases. Tiny particles of solid materials, such as dust, are also in the air.

Gaseous content of air. The two major gases in the air are nitrogen and oxygen. Nitrogen makes up approximately 78 percent of the air, and oxygen accounts for nearly 21 percent. The remaining 1 percent of air (0.93 percent) consists mainly of argon.

The atmosphere also contains minute amounts of several other gases, which include hydrogen, helium, krypton, ozone, xenon, carbon dioxide, nitrous oxide, and methane. In certain parts of the world, the air also contains small traces of ammonia, carbon monoxide, and hydrogen sulfide.

Water vapor or moisture in the air. Water vapor, or moisture which is in the air, is in the form of a gas. Each particle of water vapor, invisible to the human eye, is smaller than one-millionth of a millionth of an inch.

Air particles. Solid particles, like water vapor, are usually invisible except when they occur in great numbers. A cubic inch of air, for example, usually contains about 100,000 solid particles. Sometimes dust will contain up to 5 million particles in a cubic inch.

Besides dust, other particles commonly found in the air include salt from the seas, pollen, and microbes. High above the earth, tiny ice crystals are frequently found, and sometimes the ashes of meteors enter the earth's atmosphere from outer space.

Weight. Although not much attention is paid to the weight of air, it has a definite weight. While the air in a typical drinking glass weighs only as much as a small pill, the weight of the air around the world has been estimated to exceed 5 quadrillion (5,000,000,000,000,000) tons.

Pressure. Air pressure, too, is taken for granted, although most people learn in early childhood that air exerts approximately 14.7 psig at sea level. The column of air pressing down on a person's shoulders weighs approximately 1 ton. However, this weight is not noticed since support on all sides is afforded by an equal pressure of air.

THE ATMOSPHERE AND ATMOSPHERIC LAYERS (cont'd)

Resistance of the air. Since air is a little "sticky," it tends to resist the motion of objects going through it. A sheet of paper will not fall straight down because it keeps rubbing against the air. The paper will slide edgeways between molecules of air. The faster objects move through the air, the more air resistance they tend to meet.

Air resistance creates heat. Space vehicles, missiles, and rockets travel at such rapid speeds that air rubs past their "noses" so fast that they become red hot. In the exploration of outer space, constant efforts are being made to develop new materials which will withstand heat caused by atmospheric friction.

Air motion. Various factors contribute to the movement of air. The sun causes air to move or expand by heating it. (As warm air rises, cooler air moves slowly into its place, and as a result, winds arise.) Air constantly moves around the earth because of the motion of the earth. Air is also moved by the gravitational attraction of the moon and sun, and tides result. Still another kind of air motion is the constant motion, or vibration, of gaseous molecules that are in the air: the warmer the air, the faster the molecular motion; the colder the air, the slower the molecular motion.

Air compression. It is well known that the air in a given room can be forced under pressure into one or more small strong steel cylinders. Such air is compressed air. As the speed of air molecules increases, the pressure on them becomes greater. The air becomes warmer. For example, when a tire is pumped up by hand, the pump becomes warmer as the tire pressure increases. Lowering or reducing the pressure has the opposite effect. Air becomes cooler after it expands, slowing down the speed of molecules.

Compressed air is used, among many other ways, to inflate automobile tires and to operate pneumatic drills. Air compressed to about one two-hundredth of its normal volume is kept in steel cylinders for use aboard some ships. At the Manned Spacecraft Center, gas cylinders of numerous kinds of compressed gases are used daily in connection with manned space flight.

ATMOSPHERIC LAYERS

Overview. Those concerned with the atmosphere of the earth and the space just beyond it, have divided the atmosphere into four main layers. From the earth surface up, these layers are: the troposphere, the stratosphere, the ionosphere, and the exosphere.

Troposphere. In general, the troposphere varies in height from about 5 miles over the poles to approximately 10 miles over the equator. The temperature usually decreases about 3° or 4° for each 1000 feet of increase in altitude. At the upper level of the troposphere, the temperature over the United States remains rather constant at -67° F. Surprisingly, over the poles the temperature remains about -50° F and over the equator nearly -100° F. Most of the air, moisture, and dust of the atmosphere are in the troposphere. The most rapid changes of temperature take place in the troposphere, and, as would be expected, clouds and weather are usually confined to this level.

THE ATMOSPHERE AND ATMOSPHERIC LAYERS (cont'd)

Stratosphere. The stratosphere extends from the troposphere to about 50 miles above the earth. The stratosphere has several special features. Ozone seems to concentrate in an area between 12 and 21 miles in altitude, and a warm layer, which is probably created when sunrays hit this zone, exists above that. (A temperature of 30° F usually prevails in this warm layer about 30 miles from the surface.) Pilots prefer flying in the stratosphere to keep above the thunderstorms and snow.

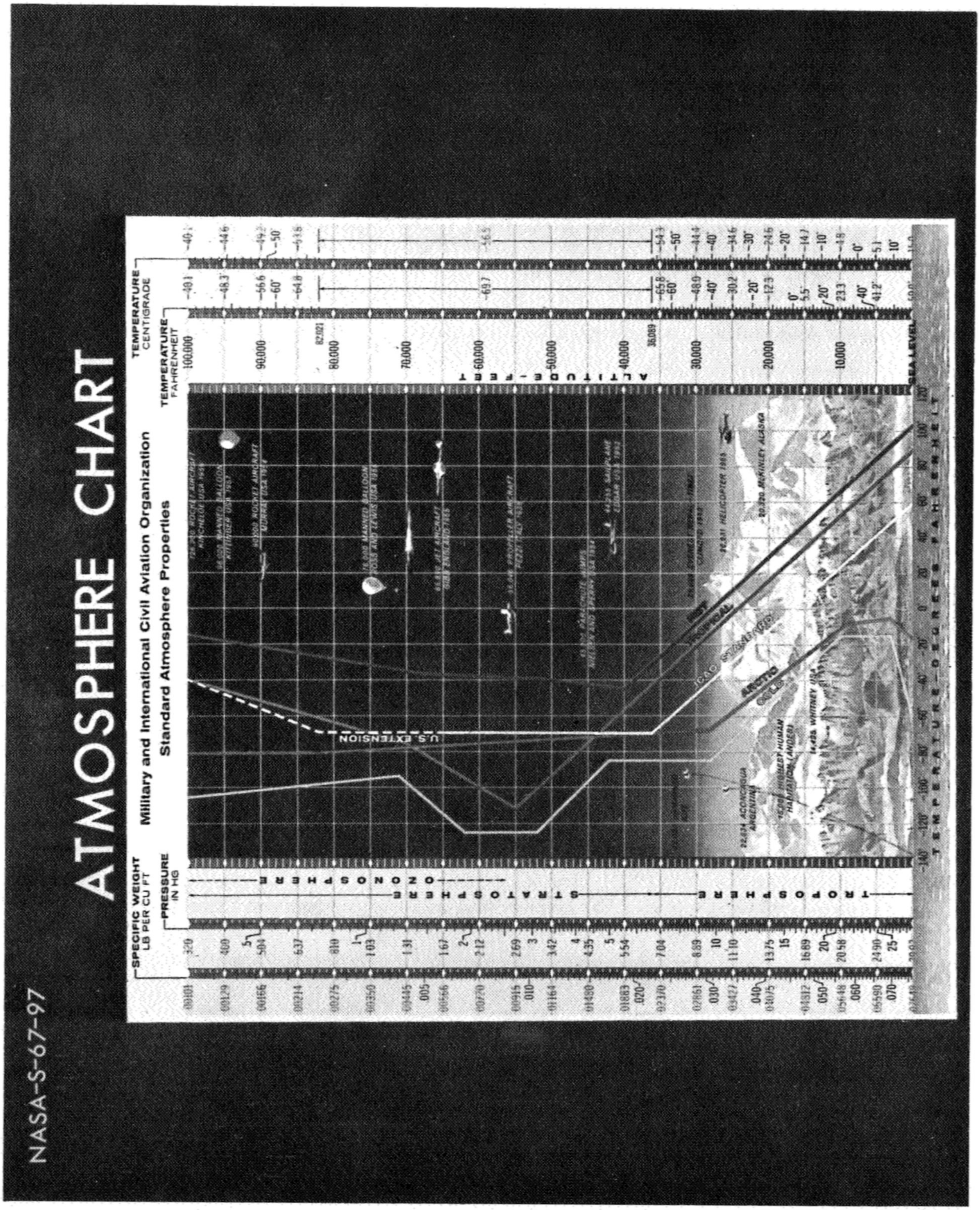
The upper stratosphere, though it contains very thin air, is windy. The so-called "jet stream" attains speeds as high as 300 mph.

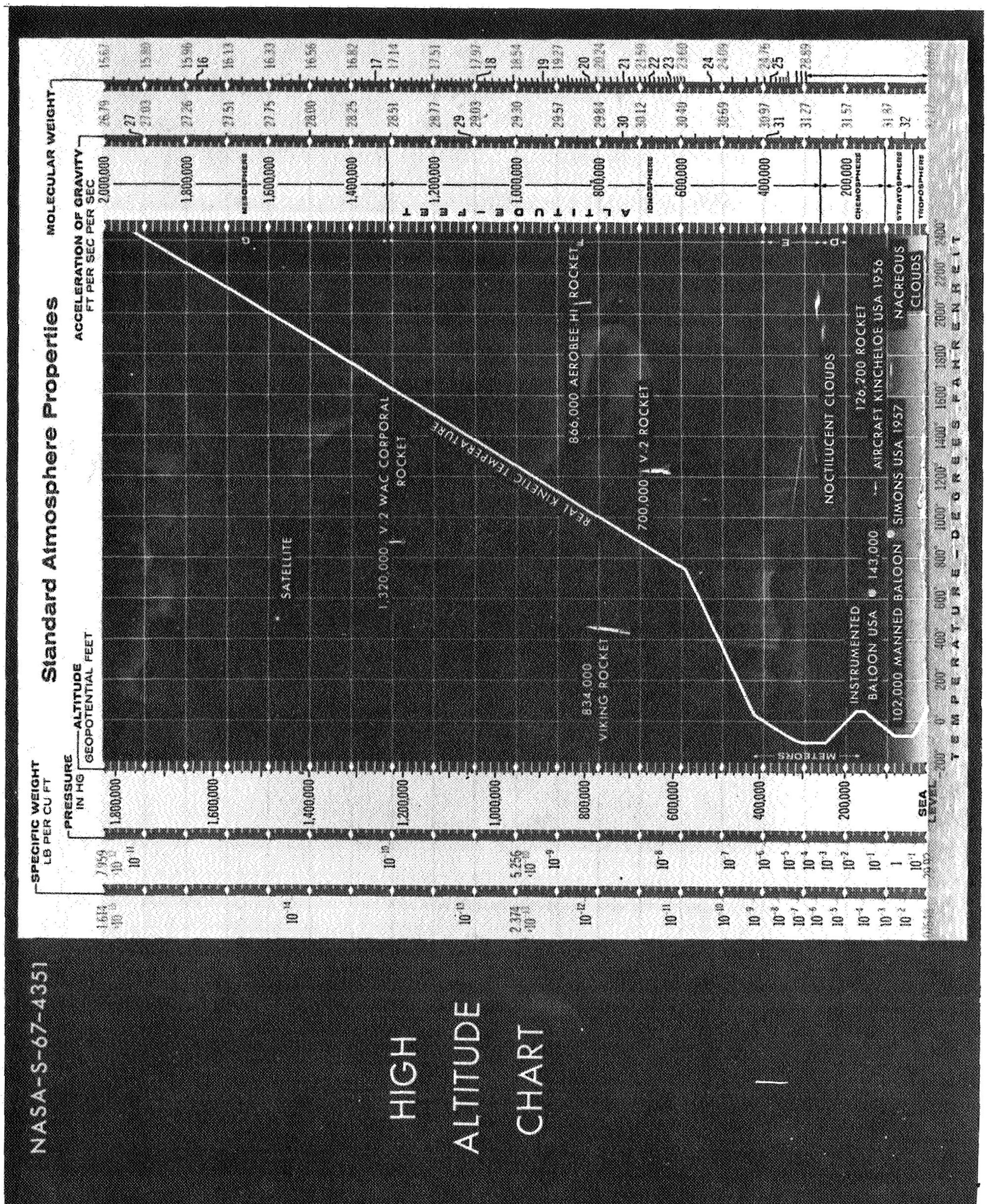
Ionosphere. The ionosphere ranges from 50 to 300 miles above the earth's surface. The air layer received its name from the ions found there. These ions, or electrically charged molecules, form when air molecules are hit by rays coming from the sun, or when they collide with high-speed particles known as cosmic rays. Meteors light up as they go into the outer air of the ionosphere. The Aurora Borealis, or Northern Lights, are sometimes visible here.

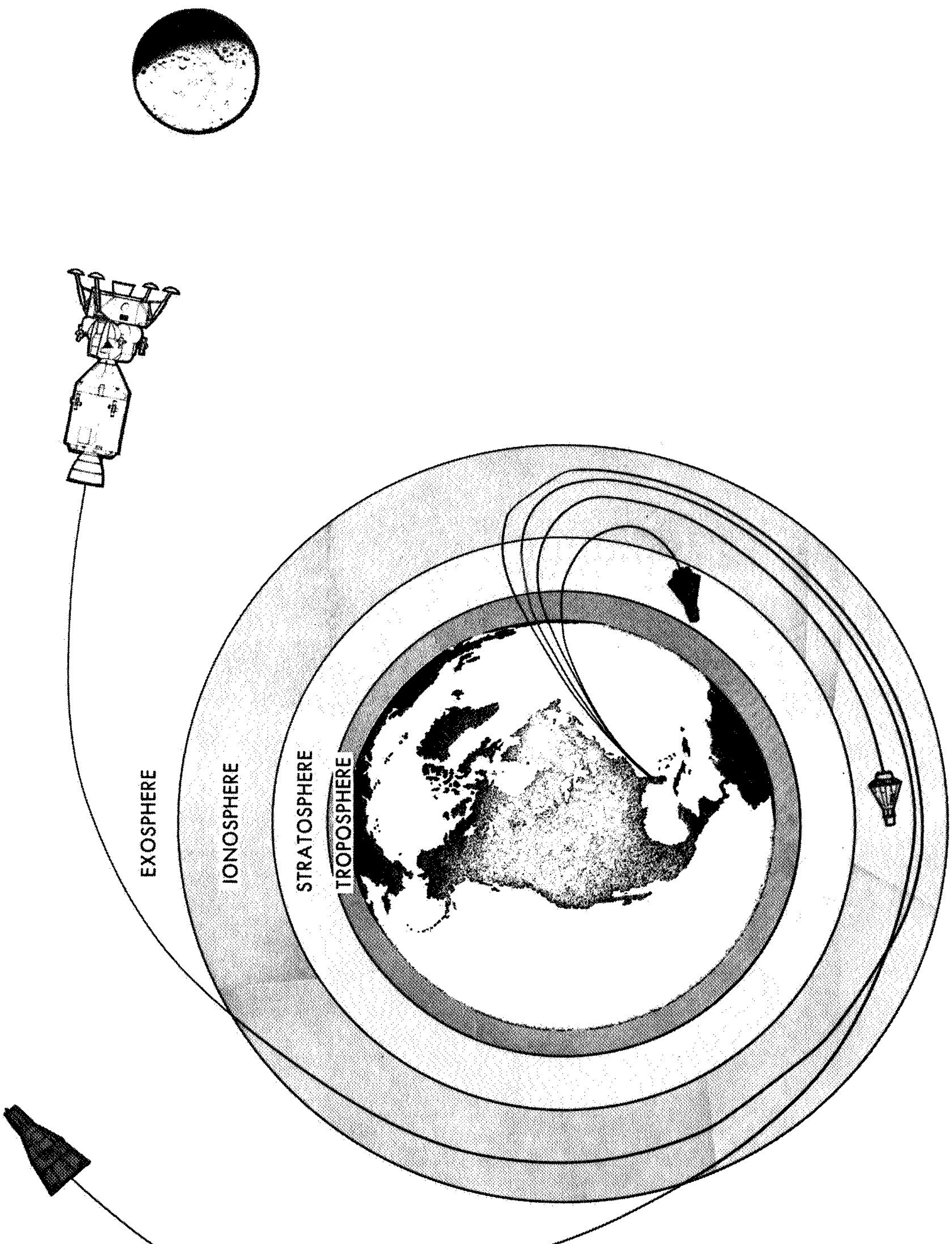
The bottom of the ionosphere has the mysterious ability to return radio waves to earth and to send short-wave messages thousands of miles. Naturally, in this layer, molecules are much farther apart than those of the lower air. Fortunately, the ionosphere shields us from the rays of the sun and from objects such as meteors entering the atmosphere.

At the upper limits of the atmosphere, air becomes nearly nonexistent.

Exosphere. The uppermost layer of the atmosphere and the beginning of space, the exosphere, commences 300 miles above the earth. Air resistance is practically nonexistent. Whereas an air molecule in the lower air may travel only one two-hundred-thousandth of an inch before colliding with another molecule, air molecules in the exosphere are farther apart than two footballs at either end of a football field. It is possible for air molecules to escape from this outer layer of the atmosphere into outer or interplanetary space where there are a few hundred or a few thousand molecules per cubic foot of space. However, because of their size, it is possible for these space molecules to travel many miles before hitting each other.

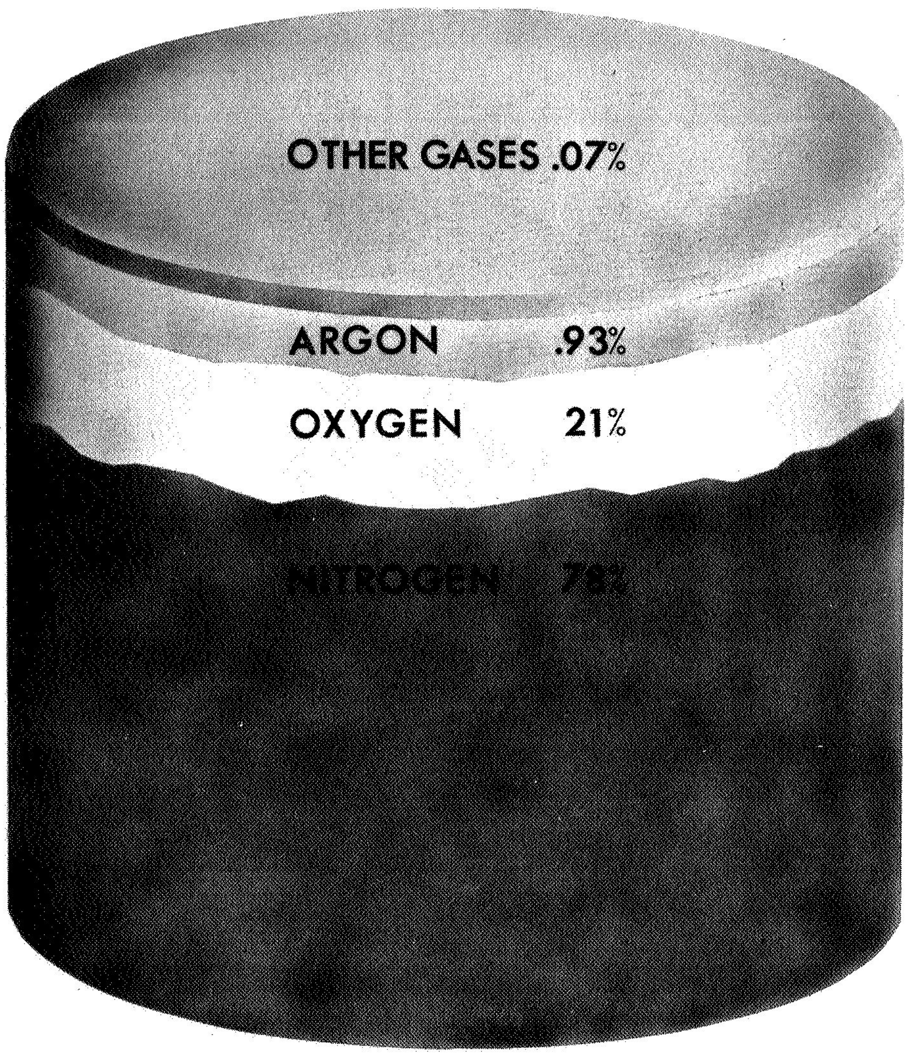

NASA-S-67-97
ATMOSPHERE CHART
Military and International Civil Aviation Organization
Standard Atmosphere Properties
STRATOSPHERE
OZONOSPHERE
TROPOSPHERE
U.S. EXTENSION
ALTITUDE - FEET
TEMPERATURE - DEGREES FAHRENHEIT
SPECIFIC WEIGHT LB PER CU FT
PRESSURE IN HG
TEMPERATURE FAHRENHEIT
TEMPERATURE CENTIGRADE
SEA LEVEL


NASA-S-67-4351
HIGH ALTITUDE CHART
Standard Atmosphere Properties
SPECIFIC WEIGHT LB PER CU FT
PRESSURE IN HG
ALTITUDE GEOPOTENTIAL FEET
ACCELERATION OF GRAVITY FT PER SEC PER SEC
MOLECULAR WEIGHT
ALTITUDE - FEET
SEA LEVEL
TEMPERATURE - DEGREES FAHRENHEIT
REAL KINETIC TEMPERATURE
SATELLITE
1,320,000 V-2 WAC CORPORAL ROCKET
834,000 VIKING ROCKET
866,000 AEROBEE-HI ROCKET
700,000 V-2 ROCKET
NOCTILUCENT CLOUDS
126,200 ROCKET AIRCRAFT KINCHELOE USA 1956
INSTRUMENTED BALOON USA 143,000
102,000 MANNED BALOON SIMONS USA 1957
NACREOUS CLOUDS
METEORS
MESOSPHERE
IONOSPHERE
CHEMOSPHERE
STRATOSPHERE
TROPOSPHERE


EXOSPHERE
IONOSPHERE
STRATOSPHERE
TROPOSPHERE

NASA
S-67-35693

GASEOUS CONTENT OF DRY AIR

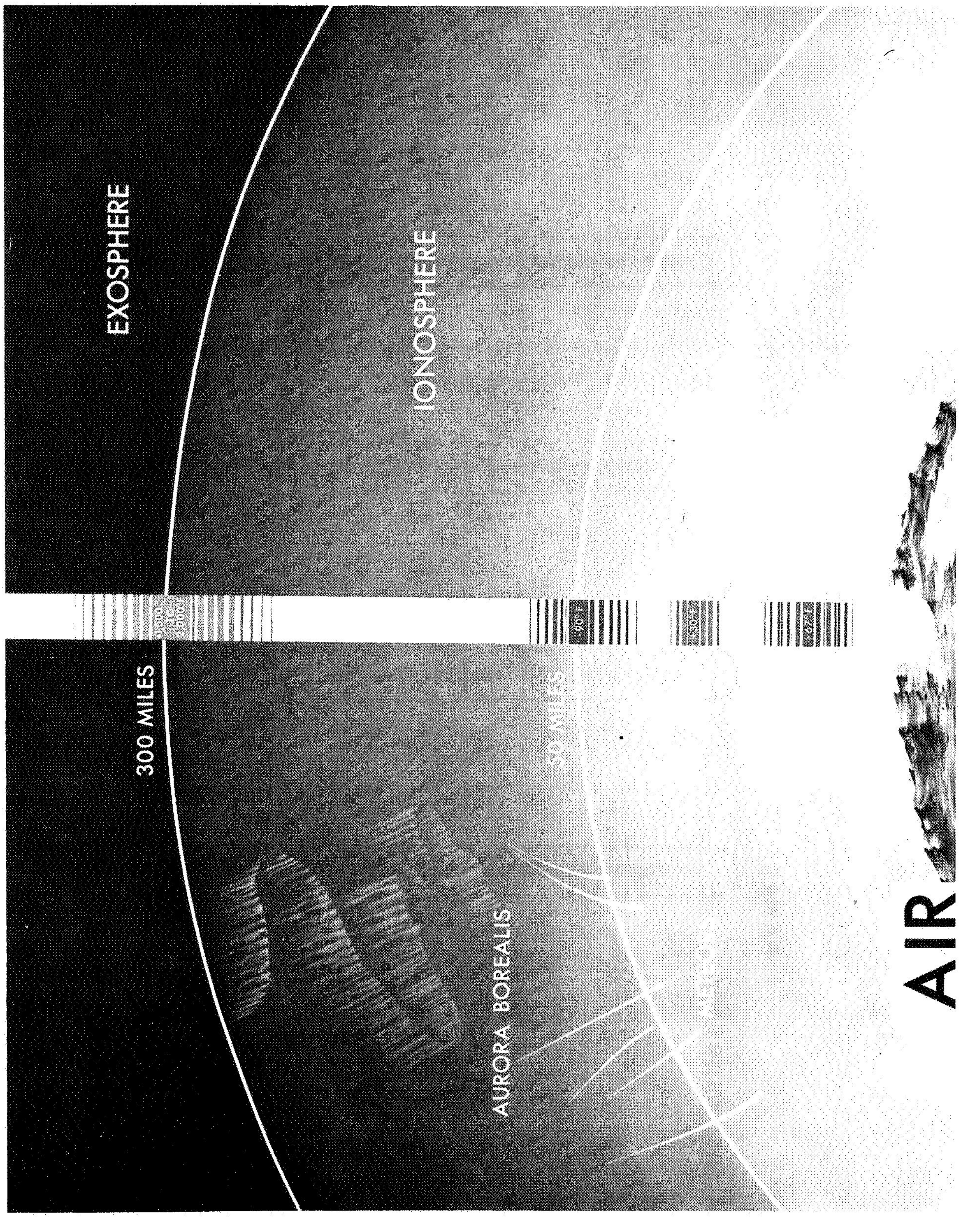


NASA-S-67-4616

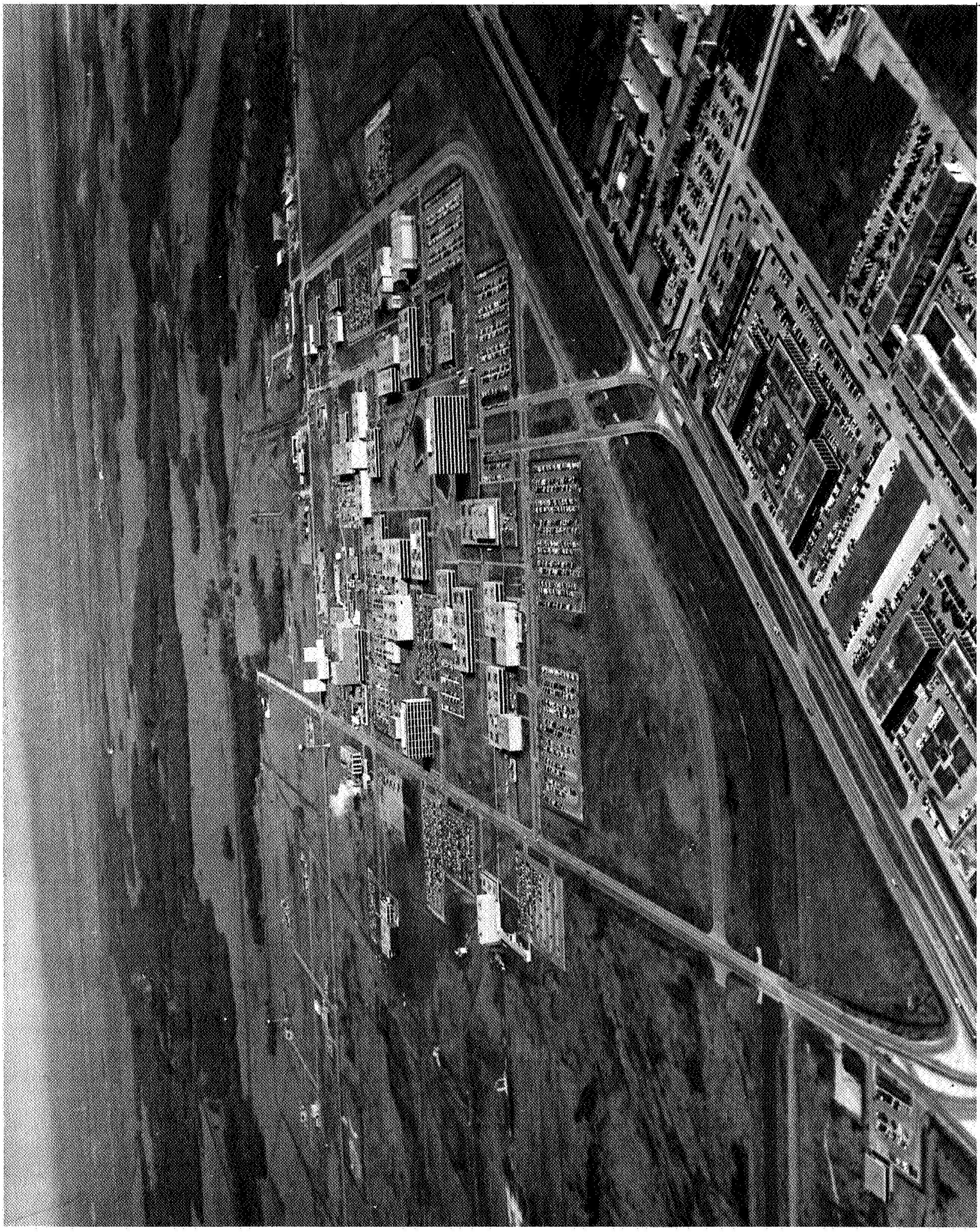
COMPARATIVE LOW TEMPERATURE CHART

	FAHRENHEIT	RANKINE	CENTIGRADE	KELVIN
WATER BOILS	212°	671.67°	100°	373.18°
WATER FREEZES	32°	491.67°	0°	273.18°
OXYGEN BOILS	-297.35°	162.32	-182.97°	90.21°
ARGON BOILS	-302.25°	157.42	-185.7°	87.48°
ARGON MELTS	-308.2°	151.47	-189.2°	83.98°
NITROGEN BOILS	-320.454°	139.21	-195.808°	77.372°
NITROGEN MELTS	-345.75°	113.92	-209.86°	64.32°
OXYGEN MELTS	-361.12°	98.55	-218.087°	55.093°
NEON BOILS	-410.95°	48.72	-246.087°	27.093°
NEON MELTS	-415.52°	44.15	-248.67°	24.51°
HYDROGEN BOILS	-422.9°	36.77	-252.762°	20.418°
HYDROGEN MELTS	-434.45°	25.22	-259.14°	14.04°
HELIUM BOILS	-452.03°	7.64	-268.928°	4.252°
ABSOLUTE ZERO	-459.72°	0	-273.18°	0

Prepared by William T. Kitts and Edwin M. Logan
NASA Manned Spacecraft Center, Houston, Texas



NASA
S-67-35694



NASA
S-67-20407

ATMOSPHERIC LAYERS

- TROPOSPHERE
- STRATOSPHERE
- IONOSPHERE
- EXOSPHERE

NASA-S-67-87

ATMOSPHERIC ELEMENTS WITH WHICH MSC IS PARTICULARLY CONCERNED

- NITROGEN
- OXYGEN
- HYDROGEN
- FREON
- HELIUM
- ARGON

NASA-S-67-88

AIR

- PROPERTIES AND CHARACTERISTICS
- COMPOSITION OF AIR
  - GASES
  - MOISTURE
  - PARTICLES
  - SPECIAL ASPECTS
    - WEIGHT AND PRESSURE
    - RESISTANCE
    - MOVEMENT
    - UTILIZATION OF AIR COMPRESSION

APPENDIX C

1. Suggested lesson plan guide accompanied by notations to the instructor(s)

2. Suggested session quiz and related answer sheet

3. Selected support materials, including the slide script entitled "Keeping Cylinders Safe," opaque projection materials, and transparencies

Suggested Lesson Plan

for

Session 3

HANDLING COMPRESSED GASES

Estimated Time	Item(s)
	1.0 Review and session introduction
	1.1 Discuss the highlights of the preceding session on the atmosphere and quality assurance.
	1.2 Point out that during this session further use of the atmosphere will be discussed.
0010	1.3 Present the following session objectives:
	a. To furnish a better understanding of the major types of compressed gases handled at this Center
	b. To stress the need for handling these gases safely
	2.0 Types of compressed gases used at the Center
	2.1 Using transparency S-67-87 as an aid, discuss the atmospheric elements with which MSC is particularly concerned.
	2.2 Define the term "compressed gas," using transparency S-67-4613 as a visual aid.
	2.3 Explain the Center policy pertaining to commercially owned high-pressure gas cylinders.
	2.4 Examine S-67-20407, aerial view of the Center, showing where different types of gases are used.
	2.5 Supplement the aerial view presentation by using the opaque projector (or chalkboard) to show the different types of compressed gases (appendix C) used in different buildings at the Center.

Estimated Time	Item(s)
	2.6 Use the opaque projector to present selected parts of figure 62-1, "Color Code for Cylinders," Part 6, Subpart 2, MSC Safety Manual (MSCM 1700).
	2.7 Present the cylinder color codes (again using the opaque projector) for compressed gases which depict the top, bands, and body colors.
	2.8 Use the display of several empty, although compatible, cylinders, such as oxygen, helium, or nitrogen, to emphasize further the color codes in item 2.6.
0035	2.9 Present transparency S-67-458 to point out the different sizes and shapes of cylinders.
	3.0 The need for handling gases safely
	3.1 Elicit from the class members and provide, in addition, several examples of aerospace accidents involving gases which have occurred at places such as Brooks AFB, Kennedy Space Center, Manned Spacecraft Center, and so forth.
	3.2 Discuss the potential hazard areas at the Center, such as the thermochemical test area, buildings 7, 32, 222, and so forth.
	3.3 Call the attention of the class to posted display chart S-67-35691, "Using Compressed Gases."
	3.4 Use the opaque projector to highlight several chart inserts mentioned in item 3.3.
0045	3.5 Have the class participants comment on articles pertaining to airline explosions (optional).
0055	C L A S S B R E A K
	4.0 High-pressure cylinders
	4.1 Project transparencies S-67-4128 and S-67-86, to introduce the film, "Working with Compressed Gases."

Estimated Time	Item(s)
0115	4.2 Present the film, "Working with Compressed Gases," and hold a followup discussion, including items from "Notes to Conference Leader" (appendix C).
	5.0 Cylinder demonstration
	5.1 Discuss "empty cylinders" properly displayed after making a check of potential safety hazards in the room (refer to transparency S-67-20077). Include aspects such as the following: a. Compatibility b. Tagging c. Securing cylinders properly d. Leaving each cylinder containing a minimum of 25 psig e. Storing "empties" apart from "fulls"
0125	5.2 Hold a brief discussion on cylinders, since numerous questions should arise from the class and/or be induced by the instructor.
	6.0 Cylinder Safety
	6.1 Introduce the slide presentation entitled "Keeping Cylinders Safe" by using the flip-chart to bring out purposes and methods of detecting defective cylinders, such as the following: a. Odor test b. Visual test c. Hammer test d. Hydrostatic test
	6.2 Give the slide presentation using the narrative script in this appendix as the guide.
	6.3 Correlate the ICC requirements — Sections (a) 73.28 and 73.84 (e) (4) — aforementioned item 6.2.
0145	6.4 Summarize briefly those salient high points of the presentation through a brief question and answer session.
	7.0 Quiz
	7.1 Administer the quiz.
0200	7.2 Discuss the quiz.

Estimated Time	Item(s)
0155	8.0 Summary and distribution of handout material
	8.1 Give a résumé of the safe handling of gases.
	8.2 Announce the topic(s) to be treated at the next session.
0200	8.3 Distribute the handout materials.

Notations to the Instructor

1. Place the poster entitled "Using Compressed Gases" on a bulletin board (or "flip-chart" rack) and be prepared to discuss at an appropriate time with the class. Hand out copies of the poster to the class participants at the end of class.

2. Prior to class, obtain properly painted cylinders, such as those used for oxygen, nitrogen, and helium for classroom display purposes. Check on the compatibility of gases and also display the cylinder handling chart. Place the display under the poster, "Using Compressed Gases." (See photograph S-67-20077.)

3. Set up the overhead transparency projector and transparencies pertaining to the film on compressed gases.

4. Prepare the motion-picture projector and screen for showing the film entitled "Working with Compressed Gases."

5. Set up the opaque projector for use with the MSC Safety Manual (MSCM 1700), and so forth.

6. Examples of accidents include: technicians killed at Brooks AFB, February 1967; Apollo astronauts killed at Kennedy Space Center, January 1967; and Brown & Root technician injured at MSC, March 1966.

7. Arrange for the class participants, prior to class, to be prepared to report on articles pertaining to airline explosions (optional).

8. Update the opaque projection item entitled "Location and Types of Compressed Gases Used at the Manned Spacecraft Center."

9. Plan to furnish specific handout items to the class.

10. Check the MSC Safety Manual "Color Coding Chart" to ascertain conformance to CGA standards.

11. Make a final verification with the guest speakers for the following day:

    a. The representative from the Central Gas Storage Facility

    b. The guest lecturer, if available, who will provide demonstrations on compressed gas safety and cylinder gas outlets and connections (optional)

12. In connection with the lecturer(s), obtain the following:

    a. Remarks for introductory purposes

    b. Parking place reservations

    c. Table and display space for the guest lecturer for the succeeding session

13. Before class, set up the slide projector and check to see that slides are in the proper sequence. Some slides and their corresponding script sections could be deleted without disrupting the continuity of the slide presentation.

14. Display photographs, such as S-67-20077, on the classroom bulletin board.

APPENDIX C

Suggested Session 3 Quiz

HANDLING COMPRESSED GASES

A. True or False

___ 1. The "hammer test" provides a means of detecting serious corrosion which can weaken the cylinder wall and thereby impair its ability to withstand pressure.

___ 2. Cylinder valves should be cracked slightly to blow dust out of the inlets because it is safe to bleed gases, especially those which are flammable and toxic.

___ 3. Safety devices protect gas cylinders under all circumstances.

___ 4. Compressed gas cylinders, which bear an ICC inspection stamp date of 5 years or more past, should be returned to the vendor at the earliest possible date for the necessary pressure test recertification and markings.

___ 5. It is illegal to ship a leaking cylinder, whether full or partially full.

___ 6. A cylinder defect characterized by metal removal known as "gouging" is caused by exposure to some corrosive atmosphere.

___ 7. When empty cylinders are being returned with a minimum of 25 psig, all valves should be closed, the cylinder valve protective caps should be installed, and the outlet caps should be replaced before shipping.

___ 8. Cylinders must be filled in accordance with the regulations of the ICC.

___ 9. Where caps are provided for valve protection, such caps will be removed from cylinders when cylinders are moved.

___ 10. Lifting magnets, sling ropes, and sling chains are recommended, when available, for handling one or more cylinders.

B. Completion

Fill in the following missing blanks, as appropriate, in the general color coding for gas cylinders:

	Gas	Upper portion of cylinder	Lower portion of cylinder
1.	Acetylene	______________	Black
2.	Hydrogen	Red	______________
3.	Helium	______________	Black
4.	____________	Green	Green
5.	Nitrogen (oil pumped)	______________	Gray

Session 3 Quiz Answers

A. True or False

1. True
2. False
3. False
4. True
5. True
6. False
7. True
8. True
9. False
10. False

B. Completion

1. Black
2. Red
3. Orange
4. Oxygen
5. Black

Script

for

KEEPING CYLINDERS SAFE[3]

Slide	Script
Slide 3	Here is a familiar scene — high-pressure gas cylinders being unloaded at a compressed gas plant. They are being returned after being out of the plant for awhile — maybe a few weeks, maybe a year or more..
Slide 4	It is obvious, from the variety of trucks at the loading dock, that the cylinders have passed through many hands — those of shippers, distributors, and customers. Where they have been or what has been happening to them is unknown.
Slide 5	Hundreds of cylinders are handled at a plant every day. They are made of high-grade steel and as safe as they can be made, but it pays to be careful.
Slide 6	A cylinder may leave the plant looking like this, with a shiny new paint job, and guaranteed to be as good as new. It may come back not much the worse for wear.
Slide 7	It may come back looking like this, but appearances can be deceiving. This may still be a perfectly good cylinder, while one that looks a lot better may have been mistreated so that it has become hazardous.
Slide 8	A defective high-pressure gas cylinder may burst with explosive violence. This cylinder ruptured under controlled conditions. It would be highly destructive if it happened while in service. The responsibility for preventing such accidents rests with the plant.
Slide 9	Regulations of the ICC, as well as state and local laws, place the responsibility for safe maintenance of high-pressure gas cylinders squarely on whoever fills the cylinders, and many company regulations go even farther than legal requirements.

[3] These slides and much of the script have been reproduced from a filmstrip prepared and produced by the Linde Division of Union Carbide, Inc.

Slide	Script
Slide 10	Some companies have developed tests to make sure that cylinders are safe. The first three — odor test for contamination, visual inspection for surface defects, and hammer test for internal corrosion — take advantage of the human senses of smell, sight, and hearing. The hydrostatic test uses special apparatus to check various properties of the steel in the cylinder.
Slide 11	By means of these tests, all damaged or defective cylinders that come back to the plants must be removed. The number varies from month to month and from one plant to another, but averages only one-half of 1 percent of all the cylinders that come in — only 5 out of every 1000.
Slide 12	It is like looking for a needle in a haystack. Cylinders cannot be "babied." They have to be checked in a routine way without "holding up the works." Though each plant performs a little differently, this is basically what the individual tests amount to.
Slide 13	The odor test illustrates certain basic ideas common to the other tests. It should be done as soon as possible on arrival of each cylinder at the plant, preferably while the cylinder is still on the loading dock. It makes use of one of the human senses, the sense of <u>smell</u>.
Slide 14	The first step is to remove the cylinder cap. The object of the odor test is to find out if the cylinder has become contaminated — with acetylene or oil, for example — either by accident or through improper use of the cylinder by a customer.
Slide 15	The odor test is no more complicated than cracking the valve and smelling the contents. Most gases sold in high-pressure cylinders are odorless, and the human sense of smell is a most sensitive device for detecting odors; so foreign substances can be detected even in the lowest concentrations that may be an explosion hazard.
Slide 16	Notice that he keeps his face away from the valve outlet. Doing this wrong entails a risk of personal injury, since there might be some dirt in the valve, which would shoot out; or there might be some irritating substance in the cylinder. The right way is to bend over <u>near</u> the valve and fan the gas toward you with your hand.

Slide	Script
Slide 17	If no pressure exists, a little compressed air can be put in the cylinder by using the fire hose and injector conveniently placed to supply oil-free air for this purpose. Never attempt to pressurize a cylinder by blowing into it. The valve may simply be clogged, and you run the risk of injury.
Slide 18	Again, the emerging gas is sniffed to try to detect anything other than the normally rusty smell of a cylinder. An alternate method of directing the gas towards your nose is to cup your hand in front of the valve outlet so that the emerging stream bounces off your hand towards your nose.
Slide 19	If a foreign odor is detected, the cylinder must be marked immediately and put aside for further examination and reconditioning. Rejected cylinders must be marked immediately after any of the tests. Otherwise, the cylinder simply moves on to the next step in the routine.
Slide 20	The next step may be visual inspection, which consists of detecting anything unusual on the outside of the cylinder. Cylinders should be checked visually whenever the opportunity arises — not just during the inspection cycle. A good habit is to look cylinders over whenever they are rolled from one place to another.
Slide 21	One thing to look for is oil or grease. If oil or grease is found on the collar or collar threads, as in this case, or on any part of the valve, the cylinder must be taken out of service immediately for cleaning.
Slide 22	It is not quite so easy to spot the small surface defects that may cause dangerous weakness in the steel of the cylinder, but an experienced man can give a cylinder a thorough visual inspection almost without seeming to do so, as he rolls the cylinder along.
Slide 23	As a cylinder is rotated for inspection, its entire surface can be seen. Practice is needed to develop the trained eye that can spot important defects among the paint scratches, so let's see what one should be looking for.
Slide 24	Here is a cylinder that has been damaged accidentally. This type of defect may be called a cut, a gouge, or

Slide	Script
	a dig, depending on its shape. The essential idea is that metal has been removed, making the cylinder wall thinner and weakening it. Another defect characterized by metal removal is pitting, which is caused by exposure to some corrosive atmosphere.
Slide 25	Surface defects without metal removal are dents and bulges. Bulges, other than those obviously caused in manufacturing, are immediate cause for removing a cylinder from service. Dents like this one may weaken the cylinder, depending on how sharply the cylinder wall is indented.
Slide 26	Both dents and metal-removal defects should be measured to find out if they fall within safe limits specified by our regulations. Width and height are measured with a steel scale, and depth is determined with a set of rocker gages like the one seen here. If the gage rocks in the defect, successively smaller sizes should be tried until one that doesn't rock is found.
Slide 27	These defects occur on all types of cylinders — not just oxygen cylinders. It is important to look over argon cylinders carefully, since their dark color makes the defects hard to spot. One of the most serious defects is found most often on argon cylinders.
Slide 28	The arc burn is generally caused by the touch of an electric welding torch against the cylinder and consists of a small crater and dab of deposited metal. Can you spot the arc burn on this cylinder?
Slide 29	It is right there, in case you didn't find it. It can be understood how easy it would be to miss a small arc burn if you were looking at the entire surface of a brown argon cylinder.
Slide 30	Even the smallest arc burn damages the steel of the cylinder wall. The crater reduces wall thickness, and a zone of hardened, brittle metal called martensite forms around the burn. This brittle zone generally contains microscopic cracks and raises an uneven stress in the cylinder wall under pressure.
Slide 31	Here is what happens when an arc-burned cylinder is subjected to high pressure. This arc-burned cylinder was intentionally ruptured in a test setup, but it could have happened while the cylinder was in service.

Slide	Script
	It is easy to see that the rupture started at the arc burn. This almost invariably happens when an arc-burned cylinder bursts.
Slide 32	As in the case of the odor test, a cylinder found to have a surface defect should always be marked to indicate the type of defect and the damaged area should be circled.
Slide 33	Every cylinder must pass one more test before it is ready for filling — the hammer test. As the odor test and visual inspection depend on the human senses of smell and sight, the hammer test takes advantage of the sense of hearing.
Slide 34	In the hammer test, each cylinder is lightly tapped with a ball peen hammer. The sound that comes out gives us essential information about the condition of the inside of the cylinder.
Slide 35 (Add sound effects.)	Most cylinders sound like this. <u>sound of good cylinder</u>
Slide 36 (Add sound effects.)	But some cylinders sound like this. <u>sound of dead cylinder</u> That is called a "dead" cylinder.
Slide 37	What makes the difference is that the inside of this dead cylinder has been badly corroded by salt air or some other corrosive atmosphere. When such a cylinder is tapped with a hammer . . .
Slide 38	. . . it is the same as when you touch a bell with your finger. Because flesh won't vibrate freely and resonantly like the metal of the bell, the sound of the bell becomes dead and dull.
Slide 39	Similarly, the heavy lining of scale and products of corrosion inside this dead cylinder won't vibrate freely with the cylinder wall, deadening the sound it makes. Therefore, the hammer test provides a means of detecting serious corrosion which can weaken the cylinder wall and impair its ability to withstand pressure.
Slide 40	Here is the right way to hammer test a cylinder. The cylinder must be standing free, not touching other cylinders or anything else that would interfere with vibration.

Slide	Script
Slide 41	Hold the hammer loosely between your thumb and fore-fingers so that it hangs freely a few inches from the cylinder.
Slide 42 (Add sound effects.)	Swing the hammer like a pendulum so that it strikes the cylinder with its own weight. Don't hit too hard. Any cylinder will ring if hit hard enough, but that is not the point of the test.
Slide 43 (Add sound effects.)	If the test is made correctly, and if the cylinder is a good one, a clear sound like this will be heard. <u>sound of good cylinder</u> Let's repeat that. <u>sound of good cylinder</u>
Slide 44 (Add sound effects.)	If the cylinder is dead, it will sound like this. <u>sound of dead cylinder</u> or even like this, if it is <u>very</u> dead <u>sound of very dead cylinder</u>
Slide 45	Again, cylinders found to be dead must be marked immediately and set aside. Sometimes deadness is caused by ice or dirt inside the cylinder, rather than corrosion. Such cylinders may be reclaimed, but only if they pass the next test to be discussed.
Slide 46	The hydrostatic test is considerably different from the others seen so far. This test is given to dead cylinders whenever found and to all other cylinders at regular intervals.
Slide 47	ICC regulations specify that every cylinder must be hydrostatically tested when it is manufactured and every <u>5 years</u> after that. These dates show when the cylinder has passed the hydrostatic test. At some point in the inspection routine, each cylinder must be checked to see if it is due for a new test.
Slide 48	The hydrostatic test measures resilience, wall thick-ness, and strength of the steel in the cylinder. Under pressure, every cylinder swells like a balloon, although this drawing is greatly exaggerated. When pressure is relieved, the cylinder may return to its original dimensions or some permanent expansion, as shown by the dotted line, may result.

Slide	Script
Slide 49	When a specific test pressure is applied and relieved, the degree of permanent expansion is an indication of changes in the metallurgical properties of the steel. Elastic expansion, which is the difference between total expansion and any permanent expansion, is a measure of wall thickness. If either measurement is beyond allowable limits, the cylinder is immediately removed from service.
Slide 50	Measurement of these expansion characteristics is made possible by this hydrostatic test unit. The test consists of a cycle of operations which permits cylinders to be processed rapidly in batches. This is necessary because from one-fifth to one-third of all cylinders passing through the plant must be tested each year.
Slide 51	After any gas pressure in the cylinders has been released, the first step is to remove the cylinder valves with this machine. The neck threads are checked and cleaned, and the top of the neck may be filed to level it off.
Slide 52	Each cylinder is filled with water. The test uses water pressure. That is why it is called a hydrostatic test.
Slide 53	By means of a spindle screwed into the cylinder neck, the cylinder is lifted and lowered into a jacket imbedded in the floor.
Slide 54	The jacket is full of water. The disk attached to the spindle is the cover of the jacket and can be clamped in place to make a watertight seal.
Slide 55	With the jacket sealed, pressure is applied to the water inside the cylinder. The pressure is 1-2/3 times the rated pressure of the cylinder.
Slide 56	The cylinder swells within the water-filled jacket. The water in the jacket is not under pressure. The jacket is simply connected by a rubber hose to an open glass tube called a burette. The expanding cylinder displaces water from the jacket, and the water pushed out rises in the burette.
Slide 57	As the water rises in the burette, the exact amount of total expansion can be measured. The water has been colored for better visibility. The cylinder is kept under test pressure for 30 seconds.

Slide	Script
Slide 58	Pressure in the cylinder is released, and the water level in the burette falls as the cylinder contracts. Here it has not quite returned to zero, indicating some permanent expansion. It will be recalled that there are allowable limits for permanent expansion as well as elastic expansion.
Slide 59	The cylinder is removed from the jacket and emptied, and if it has passed the test, a new test date is immediately stamped on its shoulder. It is good for another 5 years, unless it turns up with some other defect sooner. If this cylinder had not passed the hydro test . . .
Slide 60	. . . it would be marked immediately and placed with other defective cylinders awaiting disposition. It is essential to mark all defective cylinders as soon as they are found to make sure that they don't get back in circulation. Let's go back and review the four kinds of tests through which these cylinders are spotted.
Slide 61	The first one was the odor test, which uses the great sensitivity of the human sense of smell to detect contamination which may create an explosion hazard. Remember to protect yourself by keeping your face away from the valve opening, instead of directing the gas toward you by cupping your hand or fanning the gas stream.
Slide 62	Next was visual inspection, the search for oil and grease on cylinders, for surface defects such as cuts, gouges, digs, pitting, dents, and bulges, and especially for arc burns. Form the habit of examining cylinders visually whenever the occasion to move them arises.
Slide 63	The hammer test indicates the condition of the <u>inside</u> of the cylinder wall by means of the sound a cylinder makes when tapped with a hammer. A clear, bell-like sound means that the cylinder is good, but a "dead" sound may mean that the inside of the cylinder has become corroded, weakening the cylinder wall.
Slide 64	Finally, the hydrostatic test, which is given to dead cylinders and to all other cylinders every 5 years, checks resilience, wall thickness, and strength of the steel in the cylinder by measuring its elastic expansion and permanent expansion as pressure is applied and relieved.

Slide	Script
Slide 65	The total number of defective cylinders is not large: roughly one-half of 1 percent, or 5 out of every 1000. Of these, 1-1/2 per 1000 are removed from service for miscellaneous surface defects, 1-1/2 per 1000 for arc burn, 1 per 1000 dead in the hammer test, and 1 per 1000 for other reasons.
Slide 66	Those are average figures. You can go through long periods of applying the tests conscientiously without finding one bad cylinder, but don't be lulled into carelessness or distracted by other jobs that have to be done in the plant. A defective cylinder can turn up at any time.
Slide 67	Every cylinder that is returned to the plant must be inspected. Keeping a watch on cylinders is part of the job for everyone who works with these containers. Every man shares the responsibility of keeping his area a safe one in which to work.
Slide 68	Prevention of damage while the cylinders are out of a company's hands is also important. It is necessary to spread the word to customers, shippers, and distributors to teach them proper methods of handling cylinders for their own sakes.
Slide 69	An effective reminder is the acknowledgement that the user must sign when damaged cylinders are returned. It is important to spot defects as soon as possible and get the signature so that the customer can be charged for damage occuring while cylinders are in his care. This tends to make customers careful.
Slide 70	If everyone plays his part in this operation, these sturdy containers, whether shiny and new or battered and workworn, will keep their well-earned reputation for safety. They will remain safe to handle and safe to work with for everyone involved.
Slide 71	END TITLE

END

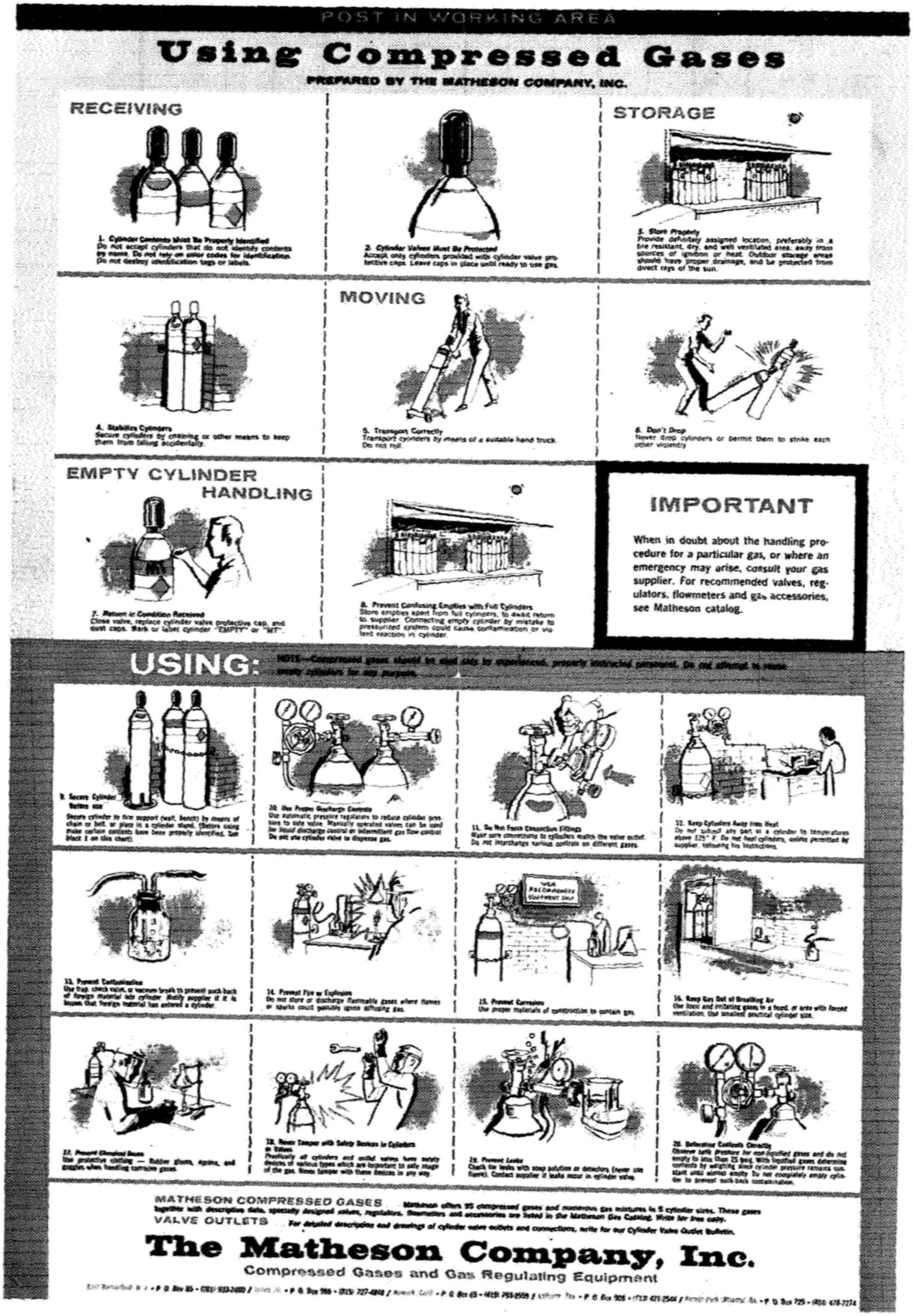

POST IN WORKING AREA
Using Compressed Gases
PREPARED BY THE MATHESON COMPANY, INC.
RECEIVING
1. Cylinder Contents Must Be Properly Identified
Do not accept cylinders that do not identify contents by name. Do not rely on color codes for identification. Do not destroy identification tags or labels.
2. Cylinder Valves Must Be Protected
Accept only cylinders provided with cylinder valve protective caps. Leave caps in place until ready to use gas.
STORAGE
3. Store Properly
Provide definitely assigned location, preferably in a fire resistant, dry, and well ventilated area; away from sources of ignition or heat. Outdoor storage areas should have proper drainage, and be protected from direct rays of the sun.
4. Stabilize Cylinders
Secure cylinders by chaining or other means to keep them from falling accidentally.
MOVING
5. Transport Correctly
Transport cylinders by means of a suitable hand truck. Do not roll.
6. Don't Drop
Never drop cylinders or permit them to strike each other violently
EMPTY CYLINDER HANDLING
7. Return in Condition Received
Close valve, replace cylinder valve protective cap, and dust caps. Mark or label cylinder "EMPTY" or "MT".
8. Prevent Confusing Empties with Full Cylinders
Store empties apart from full cylinders, to await return to supplier. Connecting empty cylinder by mistake to pressurized system could cause contamination or violent reaction in cylinder.
IMPORTANT
When in doubt about the handling procedure for a particular gas, or where an emergency may arise, consult your gas supplier. For recommended valves, regulators, flowmeters and gas accessories, see Matheson catalog.
USING:
NOTE—Compressed gases should be used only by experienced, properly instructed personnel.
9. Secure Cylinder Before use
Secure cylinder to firm support (wall, bench) by means of chain or belt, or place in a cylinder stand. (Before using make certain contents have been properly identified. See block 1 on this chart).
10. Use Proper Discharge Controls
Use automatic pressure regulators to reduce cylinder pressure to safe value. Manually operated valves can be used for liquid discharge control or intermittent gas flow control. Do not use cylinder valve to dispense gas.
11. Do Not Force Connection Fittings
Make sure connections to cylinders match the valve outlet. Do not interchange various controls on different gases.
12. Keep Cylinders Away from Heat
Do not subject any part of a cylinder to temperatures above 125° F. Do not heat cylinders, unless permitted by supplier, following his instructions.
13. Prevent Contamination
Use trap, check valve, or vacuum break to prevent suck-back of foreign material into cylinder. Notify supplier if it is known that foreign material has entered a cylinder.
14. Prevent Fire or Explosion
Do not store or discharge flammable gases where flames or sparks could possibly ignite diffusing gas.
15. Prevent Corrosion
Use proper materials of construction to contain gas.
16. Keep Gas Out of Breathing Air
Use toxic and irritating gases in a hood, or area with forced ventilation. Use smallest practical cylinder size.
17. Prevent Chemical Burns
Use protective clothing — Rubber gloves, aprons, and goggles when handling corrosive gases.
18. Never Tamper with Safety Devices in Cylinders or Valves
Practically all cylinders and outlet valves have safety devices of various types which are important to safe usage of the gas. Never tamper with these devices in any way.
19. Prevent Leaks
Check for leaks with soap solution or detectors (never use flame). Contact supplier if leaks occur in cylinder valve.
20. Determine Contents Correctly
MATHESON COMPRESSED GASES ... Matheson offers 95 compressed gases and numerous gas mixtures in 5 cylinder sizes. These gases together with descriptive data, specially designed valves, regulators, flowmeters and accessories are listed in the Matheson Gas Catalog. Write for free copy.
VALVE OUTLETS ... For detailed description and drawings of cylinder valve outlets and connections, write for our Cylinder Valve Outlet Bulletin.
The Matheson Company, Inc.
Compressed Gases and Gas Regulating Equipment

TABLE I.- LOCATION AND TYPES OF COMPRESSED GASES

USED AT THE MANNED SPACECRAFT CENTER

Building	O_2	He	H_2	N_2	Acetylene	Methane	LCO_2	A
[a]7	X	X		X	X	X	X	X
10			X		X			
15	X				X	X	X	
16				X				
29	X				X			
32	X	X	X	X	X			X
[b]33		X		X				
222	X			X			X	
262	X	X		X				X
351							X	X
353				X				
354							X	
356				X				

[a]Various gaseous and liquid mixtures are used on a regular basis for calibration purposes.

[b]Building 33 also uses liquid carbon dioxide.

NASA-S-67-86

COMPRESSED GAS CYLINDERS

- MANUFACTURE AND TESTING
- MOVEMENT AND TRANSPORTATION
- IDENTIFICATION AND VALVE PROTECTION
- STORAGE AND SECURING METHODS

NASA-S-67-4128 JUNE

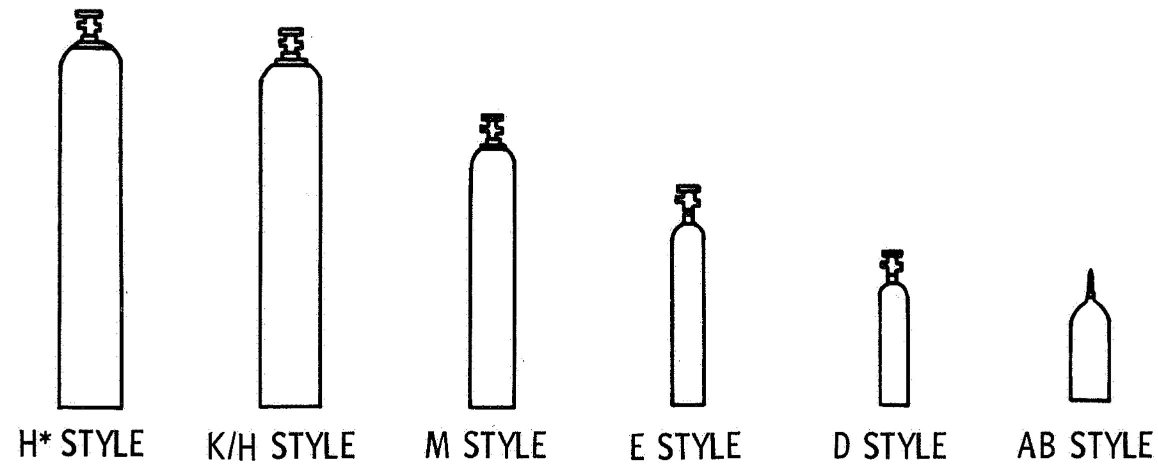
COMPRESSED GAS CYLINDERS (CON'D)

- PRESSURE REGULATORS AND VALVE CONNECTIONS
- LEAK DETECTION AND PREVENTIVE MEASURES
- VALUE OF INFORMATION--INCLUDING FIRST-AID PROCEDURES
- HANDLING LIQUEFIED GASES
- HANDLING EMPTY CYLINDERS

NASA-S-67-458

CYLINDER SIZE CHART

STYLE	OUTSIDE DIAMETER	HEIGHT	WEIGHT (EMPTY)	CAPACITY (CUBIC INCH)	DEPOSIT
H*	9-1/4"	55"	136 lbs	2990	$51.00
K/H	9"	52"	107 lbs	2675	$51.00
M	7"	43"	70 lbs	1338	$43.00
E	3-1/2"	26"	12 lbs	283	$18.50
D	3-1/2"	16"	9 lbs	171	$15.00
AB	4"	14"	4 lbs	84	$14.00



* USED IN ARGON AND METHANE SERVICE

NASA-S-67-454

COMPRESSED GAS ASSOCIATION (CGA) FITTINGS

NUMBER	TYPE THREAD	TYPE SEAL	USED FOR
CGA 280	.745 - 14NGO - RH - EXT	ROUND	LESS THAN 10% CO_2 IN OXYGEN
CGA 320	.825 - 14NGO - RH - EXT	FLAT WASHER	CO_2 AND MANY MIXTURES CONTAINING CO_2
CGA 350	.825 - 14NGO - LH - EXT	ROUND	CARBON MONOXIDE, HYDROGEN AND METHANE. ALL MIXTURES CONTAINING 1.0% OR MORE OF ANY FLAMMABLE GAS. STERILIZING MIXTURES. DEUTERIUM IN LARGE CYLINDERS
CGA 540	.903 - 14NGO - RH - EXT	ROUND	OXYGEN AND MIXTURES WHEN OXYGEN IS MAJOR CONSTITUENT, EXCEPT CO_2 MIXTURE
CGA 580	.965 - 14NGO - RH - INT	ROUND	AIR, ARGON, HELIUM AND NITROGEN. MIXTURES OF THESE AND/OR OTHER INERT GASES CONTAINING LESS THAN 1.0% FLAMMABLES
CGA 860	FLUSH; YOKE CONNECTION	FLAT	DEUTERIUM AND CERTAIN MIXTURES IN SMALL MEDICAL TYPE CYLINDERS

APPENDIX D

1. Suggested lesson plan guide accompanied by notations to the instructor(s)

2. Suggested session quiz and related answer sheet

3. Selected support materials, including the exhibit, "Over Pressure Protection for Cylinders and Vessels," opaque projection materials, and transparencies

Suggested Lesson Plan

for

Session 4

COMPRESSED GASES AND RELATED ASPECTS

Estimated Time	Item(s)
	1.0 Review of preceding session and objectives for this session
	1.1 Stress the types of gases handled at the Center, the need for handling these gases safely, and the salient aspects of both the film and demonstration on empty cylinders. Use transparencies S-67-85 and S-67-86 to assist in reviewing the film. Use the MT cylinders already on display for review purposes.
0010	1.2 Presentation of the objectives for this session.
	a. To become familiar with the safe handling of compressed gases stored in high-pressure cylinders
	b. To gain awareness of the location and operation of the MSC central gas storage system
	c. To become cognizant of the use of large high-pressure gaseous storage systems (fixed and portable) used throughout the Center
	d. To become familiar with the safety aspects of cylinder valves, outlets, and connections
	e. To become familiar with the use and safety aspects of the backpack life support system
	2.0 Central Gas Facility
	2.1 Display S-67-29818 and S-67-29819, photographs of the Central Gas Storage Facility (on the bulletin board and/or the opaque projector) and indicate that this facility will now be treated in some detail.

Estimated Time	Item(s)
	2.2 Introduce the guest speaker, a representative from the Center Supply Branch.
0030	2.3 Have the guest lecturer include the following in his presentation:
	a. Use of the map depicting the location of the facility
	b. Needs and purposes of this facility
	c. Operation and function of the facility
	d. Requirements for personnel handling compressed gases
	e. Short- and long-range trends and problems associated with the facility
	f. Question and answer session
	2.4 Make a field trip to the Central Gas Storage Facility (optional). (Refer to appendix L.)
	3.0 Utilization of compressed gas at the Manned Spacecraft Center
	3.1 Discuss the use of standard (220 cu ft) industrial gas cylinders.
	3.2 State the uses being made of standard high-pressure tube trailers and fixed storage tanks. Remind the class participants that a photograph of these tanks, S-67-44002, is displayed on the bulletin board.
0050	3.3 Discuss the industrial gases used at MSC which exceed 5000 psig and give the locations, uses, and special safety measures taken with these gases.
0100	C L A S S B R E A K
	4.0 Cylinder valves, outlets, and connections

Estimated Time	Item(s)
	4.1 Call attention of the class to photographs of overpressure safety protection devices on the bulletin board, such as S-67-36445.
	4.2 Exhibit the actual pegboard display on "Over Pressure Safety Devices."
	4.3 Discuss the following, based in part on "Highlights from a Presentation on Over Pressure Protection for Cylinders and Vessels" (appendix D):
	a. Overpressure protection through the use of relief devices
	b. Codes, primary and secondary relief requirements, and available relief devices
	c. Location and mounting of relief devices
	d. Safe disposal of fluids discharged from pressure relief devices
	4.4 Explain the requirement for pressure-indicating gages to meet designed specifications, to be calibrated periodically, and to be properly cleaned for specific utilization.
0120	4.5 Summarize briefly this section on overpressure protection.
	5.0 Backpack life support system
	5.1 Introduce the guest lecturer, a representative from the Center Fire and Rescue Department.
	5.2 Arrange for the guest lecturer to include the following in his presentation:
	a. Needs and purposes of the backpack at this Center
	b. The major components of the backpack
	c. Operation and functions of the backpack

Estimated Time	Item(s)
0145	5.3 Have the guest speaker utilize several class participants to don and check out the apparatus, and then do the following.
	a. Discuss changing air cylinders and cleaning and storing the backpack
	b. Summarize the backpack life support system and conduct a brief question and answer session
	c. State that the ventilator and portable life support system (PLSS) will be discussed in session 10
	d. Provide the handout materials as appropriate (optional)
	6.0 Session assessment
	6.1 Administer the quiz.
	6.2 Discuss the quiz items.
	7.0 Summary and distribution of the handout materials
	7.1 Summarize the session and announce the topic for the next session.
0200	7.2 Distribute the handout items.

Notations to the Instructor

1. Set up the overhead transparency projector for review covering the major items on film — transparencies S-67-85 and S-67-86.
2. Place on display S-67-20407, "Aerial View of the Manned Spacecraft Center," for Central Storage Facility location identification purposes.
3. Have notes readily available for background introductory remarks on both speakers.
4. Set up the exhibit on "Over Pressure Safety Devices" prior to the beginning of this session.
5. Place various pictures of overpressure protection devices and the Central Gas Facility on the bulletin board prior to class.

6. Cylinders which were on display for "handling of compressed gases" should remain on display for this session.

7. Make comments on "Highlights from a Presentation on Over Pressure Protection for Cylinders and Vessels." (appendix D)

8. Insure that both guest speakers are aware of the time and place of presentation and make arrangements to have required audiovisual aids and equipment properly set up prior to the time of presentation.

9. Consider the possibility of making a field trip to the Central Gas Storage Facility during or after class. (Refer to appendix M, section 3.)

10. Plan to furnish the handout items to the class.

Suggested Session 4 Quiz

COMPRESSED GASES AND RELATED ASPECTS

A. True or False

___ 1. ICC regulations require that cylinders be inspected, tested, and so stamped by the vendor, at least once each year.

___ 2. Cylinder valves, when attached to a system, should be opened slowly and the system observed for leaks.

___ 3. Once a leaky cylinder valve is found, an attempt should be made to repair it or close it with a wrench.

___ 4. Oxygen valves, regulators, gages, and other fittings should be lubricated with oil or some type of combustible substance.

___ 5. Overpressure protection through the use of primary and secondary relief devices is the first line of defense against explosions or failure of pressure vessels and connecting systems.

___ 6. Cylinders containing hydrogen preferably should be stored near cylinders containing oxygen or other combustible gases.

___ 7. A toxic gas is poisonous, exerting a chemical action on body tissue and preventing it from absorbing oxygen from the blood.

___ 8. Whenever possible, purge or blow out lines with compressed oxygen.

___ 9. An airborne-particulate hazard, fibrosis-producing dust, can cause growth of scar tissue in the lungs.

___ 10. High-pressure bottles, whether full or supposedly empty, should be secured by means of chains or similar fastening devices so that they cannot be accidentally knocked over.

___ 11. Rupture disks are frequently used beneath conventional safety or relief valves, thereby affording protection to critical valve surfaces.

___ 12. Since safety is of prime importance, system design layouts should permit the rupture disk assembly, safety, or relief valves to perform their intended function(s) satisfactorily.

___ 13. Life support systems always should be used in areas where known atmospheric contaminants exist.

___ 14. A backpack life support system can be used continuously for periods exceeding 2 hours without changing air cylinders (bottles).

Session 4 Quiz Answers

A. True or False

1. False
2. True
3. False
4. False
5. True
6. False
7. True
8. False
9. True
10. True
11. True
12. True
13. True
14. False

APPENDIX D

HIGHLIGHTS FROM A PRESENTATION ON OVER PRESSURE PROTECTION FOR CYLINDERS AND VESSELS

by

J. E. (Bill) White

Black, Sivalls and Bryson, Inc.

Introduction

Overpressure protection through the use of primary and secondary relief devices is the first line of defense against explosions or failure of pressure vessels and connecting systems.

These devices are safety valves, relief valves, frangible disk (rupture disks), and combinations of safety valves and rupture disk. Each has its own purpose, but the common denominator is the cognizance of the fact that every pressure vessel is a potential bomb.

Hazards are not necessarily limited to flammables. One large chemical plant reports that its most serious explosion involved the entrance of critical traces into a water tank. There have been many cases of hot water boiler explosions and air-receiver explosions.

The consequences of serious injury to personnel, even possible loss of life, precludes the dependence upon an insurance policy. Recognizance of the indispensable functions of applicable codes, inspections, and regulatory agencies is necessary to police installation and maintenance procedures. From a financial aspect alone, insurance cannot compensate for the disruption of production or other effects of pressure vessel failure or relief device malfunctions.

A leaking relief device is a hazard from the standpoint of safety to personnel and a contributory factor to fire. A leaking relief device also constitutes an economic loss proportional to the product being processed or stored.

The pertinent point is that a pressure vessel may fail at pressures lower than the maximum allowable working pressure used in design because of reduction in tensile strength caused by exposure to fire. Insulation, water spray, and depressuring facilities are some of the methods which offset this effect. Pressure vessels can fail in a fire, even though adequately protected from exposure.

The control of any safety program starts with top management in any organization, and that control should extend downward to the inclusion of the operations and maintenance departments.

A safety department cannot function properly, no matter how well trained the personnel may be and no matter how fine the equipment, unless they have the full support of management with authority to enforce safety procedures.

The safety department must have the final word in the following matters:

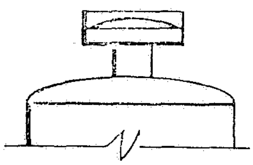
1. The sizing and selection of pressure relief devices
2. The set pressure of these relief devices
3. The physical location of the relief devices with respect to the source over-pressure
4. The testing and maintenance procedures

Codes — Design Pressure — Relief Requirements — Available Devices Codes

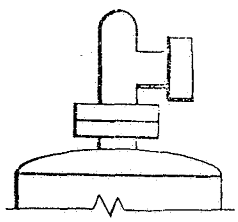
The following are some of the codes which dictate the requirements for pressure relief devices:

1. ASME unfired pressure vessel code
2. ASME boiler and pressure vessel code
3. ASA B-9 safety code for mechanical refrigeration
4. ASA B-19.1 safety standards for compressor systems
5. U.S. Coast Guard Marine Engineering regulations, booklet CG-115
6. API guide for inspection of refinery equipment, chapter 15
7. API RP 520 Design and Installation of Pressure Relieving Systems
8. National Board of Fire Underwriters, Pamphlet #30

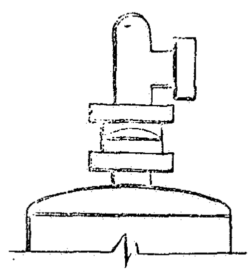
Relief Requirements.—



SAFETY HEAD ONLY
Primary Relief



RELIEF VALVE ONLY
Primary Relief



SAFETY HEAD IN SERIES
WITH A VALVE
Primary Relief

Primary relief: To comply with the ASME Code, the pressure setting of a primary relief device should not exceed the maximum allowable working (design) pressure of the pressure vessel. The primary relief device should be sized to prevent a pressure buildup greater than 10 percent above the maximum allowable working pressure when the relief device is at full capacity. Section 8 of the ASME Boiler and Pressure Vessel Code (Unfired Pressure Vessels), 1962 Edition, Paragraph UG-125 (c) states the following:

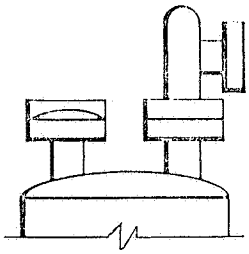
> "All unfired pressure vessels other than unfired steam boilers shall be protected by pressure relieving devices that will prevent the pressure from rising more than 10 percent above the maximum allowable working pressure, except when the excess pressure is caused by exposure to fire or other unexpected source of heat."

If the pressure vessel is vulnerable to fire or other unexpected sources of heat, additional pressure-relieving devices may be required to comply with the ASME Code. The additional devices must be sized so that their combined total capacity will prevent the pressure from rising more than 20 percent above the maximum allowable working pressure. Paragraph UG-125 (d) from the same ASME Code states the following:

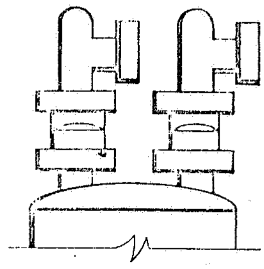
> "Where an additional hazard can be created by exposure of a pressure vessel to fire or other unexpected sources of external heat (for example, a vessel used to store liquified flammable gases), supplemental pressure-relieving devices shall be installed to protect against excessive pressure. Such supplemental pressure-relieving devices shall be capable of preventing the pressure from rising more than 20 percent above the maximum allowable working pressure of the vessel. A single pressure-relieving device may be used to satisfy the requirements of this paragraph and (c), provided it meets the requirements of both paragraphs."

If more than one pressure device is used to satisfy the requirements of Paragraphs UG -125 (c) and (d), only one unit must be set at or below the maximum allowable working pressure of the vessel. Additional protective devices required to meet the 10 percent requirement may be set up as high as 105 percent of design pressure. Additional protective devices required to meet the 20 percent requirement may be set as high as 110 percent of design pressure.

Secondary relief:



SAFETY HEAD IN SERIES
WITH A VALVE
Primary Relief
SAFETY HEAD ONLY
Secondary Relief



SAFETY HEAD IN SERIES
WITH A VALVE
Primary Relief
SAFETY HEAD IN SERIES
WITH A VALVE
Secondary Relief

It is extremely important to define the secondary relief device clearly because the reference to 10 percent and 20 percent accumulation in the ASME Unfired Pressure Vessel Code has often been misinterpreted.

There are times when exothermic reactions or "unknowns" cause pressure to rise in a vessel or system even though code requirements for primary relief devices have been followed. If the rate of pressure rise is extremely fast — in micro- or millisecond measurement — a safety head is frequently used as the standby relief device. In this case, maximum pressure setting of the secondary relief device is at or below the test pressure of the vessel. This practice is permissible because the ASME Unfired Pressure Vessel Code is not involved, provided the primary relief devices with a set pressure at or below the maximum allowable working pressure have adequate capacity to prohibit a pressure buildup greater than 10 percent or 20 percent when the relief device(s) are at full capacity.

The National Board of Boiler and Pressure Vessel inspectors states the following:

> "If the vessel is provided with relief devices to control the pressure within the 10 percent or 20 percent limits as defined in the Code, additional relief devices may be added and set at any pressure below the test pressure of the vessel."

Available relief devices: Generally, one of the following devices and/or combination of devices is used:

1. Safety valve
2. Relief valve
3. Safety relief valve
4. Safety head/rupture disk
5. Relief valve — rupture disk combination

Location and Mounting of Relief Devices

Relief devices always should be installed in a manner which will permit them to operate at full capacity. No other major restriction to flow should be permitted in the connecting piping.

To assure an adequate installation, relief equipment should be given as advantageous a location as possible to eliminate fouling and also to avoid any change of relieving fluid in a state other than orginally intended.

Relief devices should be located as close to the source of pressure as it practical to secure pressure relief quickly. Relief devices should have amply sized inlet connections.

The installation of relief devices directly on nozzles from pressure vessels is common practice. Where several relief devices are required for a given pressure vessel or unit, the devices may be installed on a manifold attached directly to a nozzle from the vessel.

Operating vessels or accumulators which generally operate partly filled with liquid should have the relief devices mounted on top. Among the advantages of a top location is the removal of noncondensable gases by operation of the relief devices. This location would satisifactorily care for the release of generated vapors. If the over-pressure cause were an accumulation of noncondensable gases, the cause would be removed when the relief devices operated.

Operating vessels normally full of liquid could have the relief device mounted at any convenient location. If the relief requirement is not for vapor generation, however, the top position would be preferred, since vapor generation from fire exposure might be a possibility. The protection of a vessel from excess pressure caused by vapor generation from fire requires the removal of a volume of the contents equal to the volume of vapor generated.

If the relief requirement in any vessel is for vapor generation, the relief device should be located in a space where vapor accumulates.

Relief devices sometimes may be placed at a particular location on a vessel or pressure unit so that it is in contact with a less corrosive fluid than at an alternate location.

Relief devices can be installed on that portion of a vessel or pressure system at which overpressure is most likely to originate, to provide rapid pressure relief and possibly eliminate operational upsets further downstream in the system under consideration.

The installation of the relief device or devices on lines to or from a particular vessel may be more advantageous and economical. This method of installation is satisfactory if a reasonable assurance exists that no stoppage can occur between the vessel and the relief device inlet, and if the line on which the relief device is located can provide ample capacity for the device.

Rupture disks frequently are used beneath conventional safety or relief valves, thereby affording protection to critical valve surfaces.

Even though the safety or relief valve workable parts may be protected by the application of a rupture disk assembly to the valve inlet, there may be problems encountered which could affect performance of the rupture disk. Inlet piping to relief devices may become plugged by deposition of solid materials. This deposition resulting from coking or salting may form a solid plug or a severe restriction, prohibiting satisfactory operation of the relief device during an over-pressure emergency. Plugging due to coke formation may indicate that a better location should be found for the relief device. Interference from excessive salt deposits or the solidification of other materials in relief device inlet lines may be eliminated by external steam tracing and insulation of the inlet piping if the salt deposit or other product media comes from cooling. If salting out cannot be eliminated, flushing streams may be introduced beneath the relief device. If the deposited material is soluble in petroleum fractions, a hydrocarbon steam may be injected below the relief device. For water-soluble deposits, and where the process in use permits, saturated steam may be similarly introduced. If the process prohibits the use of saturated steam, inert gases or superheated steam may be introduced to create a blanketing effect for preventing undesirable solidification or deposits.

Extremely viscous fluids may congeal in the inlet piping to the relief device. A satisfactory precaution against this occurence is in the use of external steam tracing and insulation of the inlet piping, as well as the inlet flange and/or portion of the relief device.

Safe Disposal of Fluids Leaving Pressure-Relief Devices

Disposal of the fluid escaping from the relief device should not influence the requirements for pressure vessel protection. In actual practice, however, back-pressure in a relief collector system does affect pressure vessel protection by tending to decrease the rate of flow through a discharging relief device and, as a result, increases the pressure rating of a rupture disk or a spring-loaded safety or relief valve not in operation. If the installation dictates the mounting of a safety or relief valve to the discharge side of a rupture disk assembly, with considerable piping involved at the valve outlet, and with back-pressure being developed when the valve functions, valve designs of the balanced type (bellows, piston, or diaphragm) should be evaluated.

The degree of hazard from relief device discharge varies considerably, depending upon the nature of the fluid and the surroundings. Hydrocarbons and gases lighter than or as dense as air usually can be vented directly to the atmosphere, if the venting occurs at an elevation which permits the vapors to diffuse into the atmosphere beyond the lower limit of combustibility prior to reaching an ignition source.

Corrosive and toxic fluids cannot be safely released directly into the atmosphere. Since any accumulation of hydrocarbon liquid is recognized as a potential fire hazard, such liquid released by relief devices should be removed through a collector system to some disposal point. Stable hydrocarbon liquids may be safely discharged to other locations.

Rupture Disk Location When the Protected System Warrants the Discharge of Gas or Liquids to the Atmosphere

The desirable mounting of the safety head to a pipe section or vessel is reflected in figure 1, which follows. If the layout of an existing pressure system to be protected dictates the location of the rupture disk with discharge in a horizontal position (free vented), it is suggested that the location be at a higher elevation than the surrounding equipment or at a point which would prohibit personnel from coming in contact with the discharge opening. If the location of the relief device does not permit an elevation which would prohibit exposure of personnel and surrounding equipment, it is suggested that consideration be given to the baffle plate arrangement as described in figure 2. Even though this arrangement may afford some protection, it is generally agreed that safer practices can be realized by having the discharge at or extended to a location which would prohibit personnel exposure to product discharge. This would also eliminate or minimize the possibility of discharged vapor ignition or damage to the surrounding equipment or property within the process area.

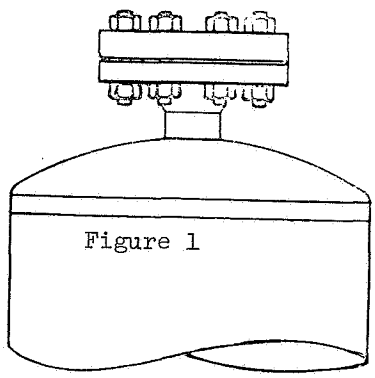


Figure 1

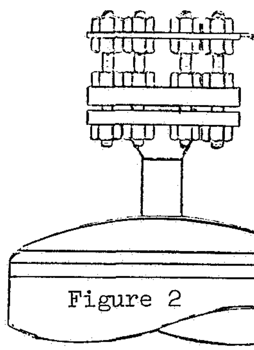


Figure 2

Conclusion

A safe operation depends not only upon the degree that safety is incorporated into every phase of the complete design but also the effectiveness of the communication with the people involved with the operation.

The assembling of pertinent data into one report that will call attention to the safety items needing attention should result in fewer omissions and a clearer understanding of the hazards involved.

Profit is proof of a properly designed and operated unit; loss proves that too great a risk has been assumed.

Safety cannot be willed to an enterprise. It must be earned, and the most effective way yet devised is through teamwork.

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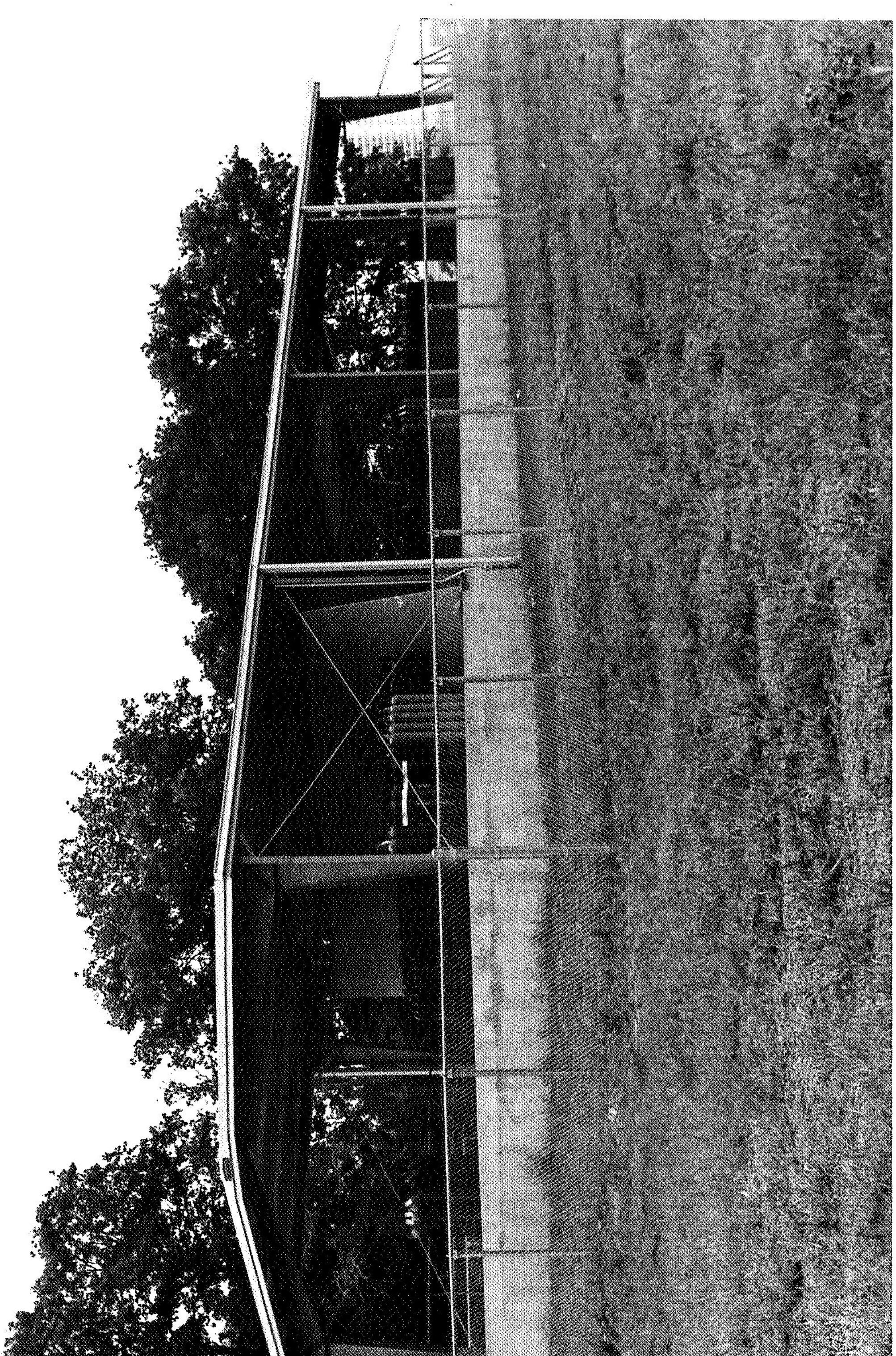

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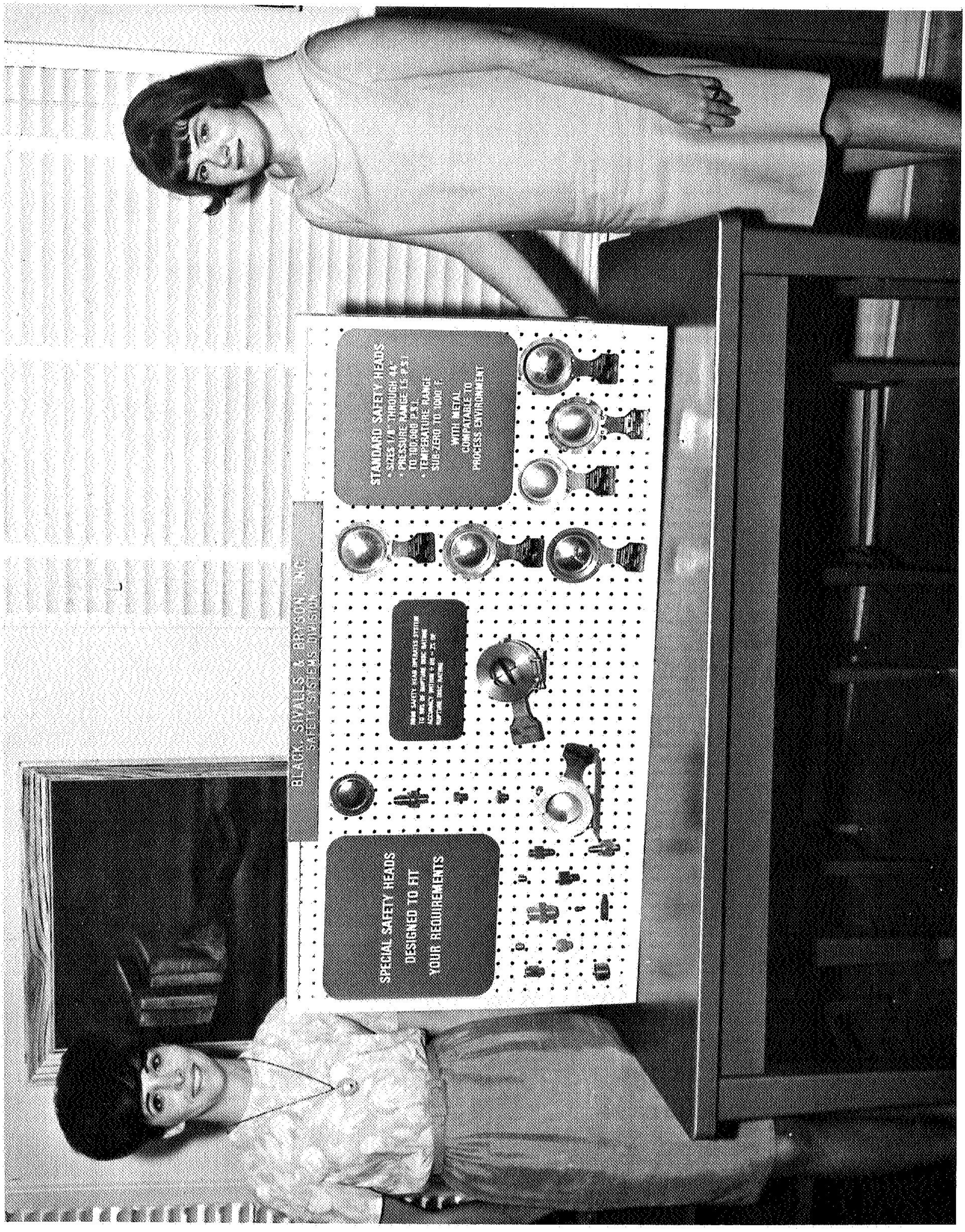

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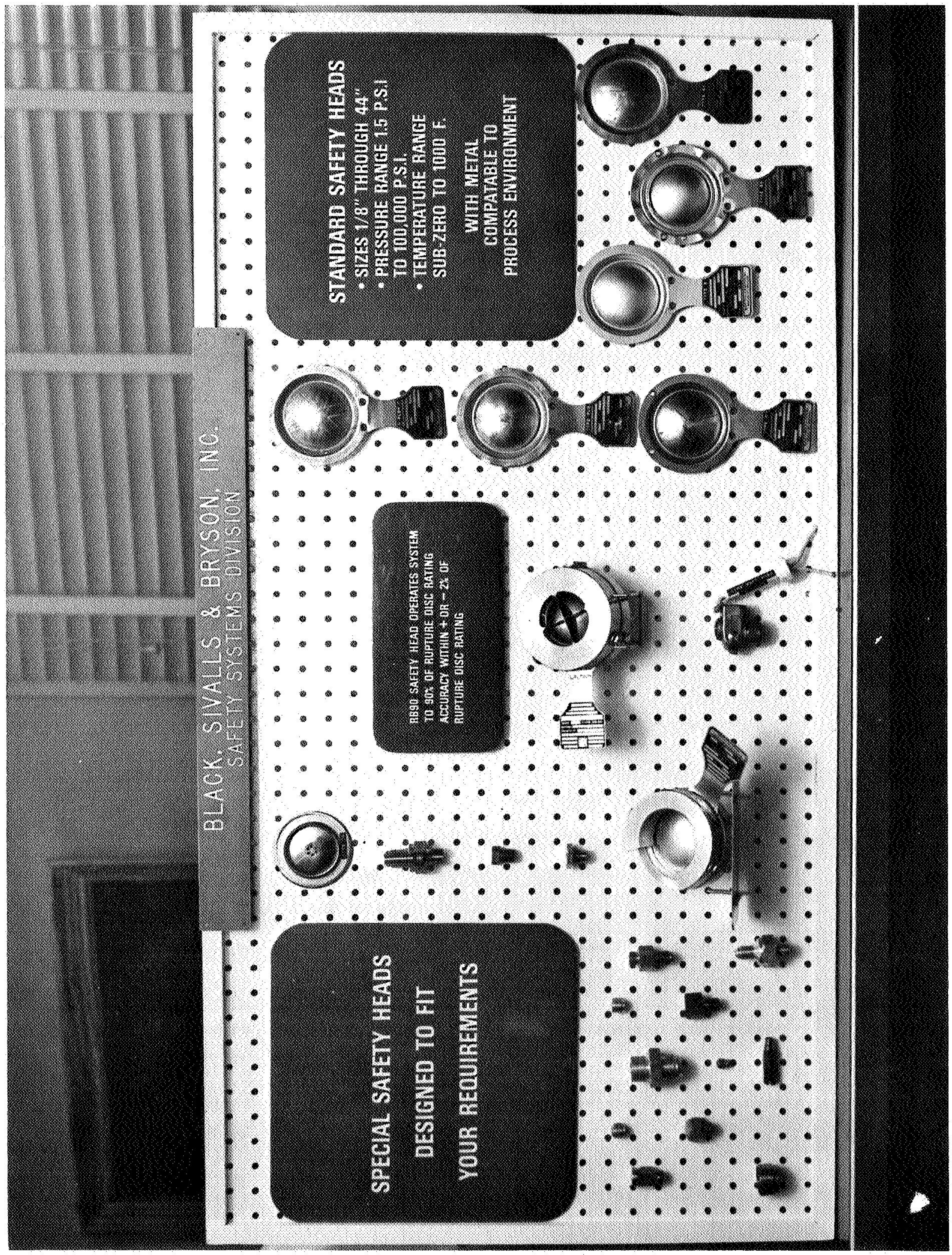

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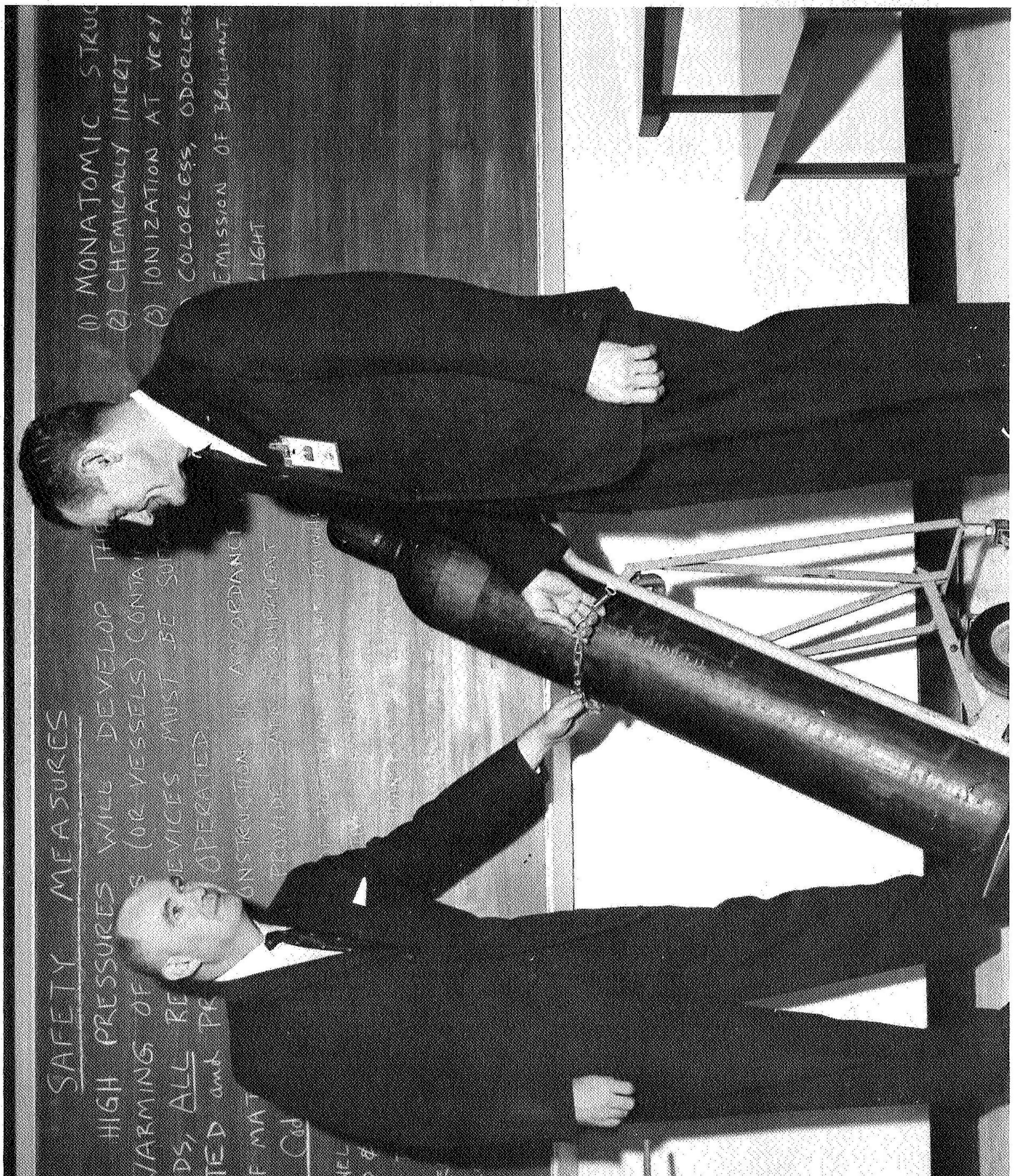

NASA
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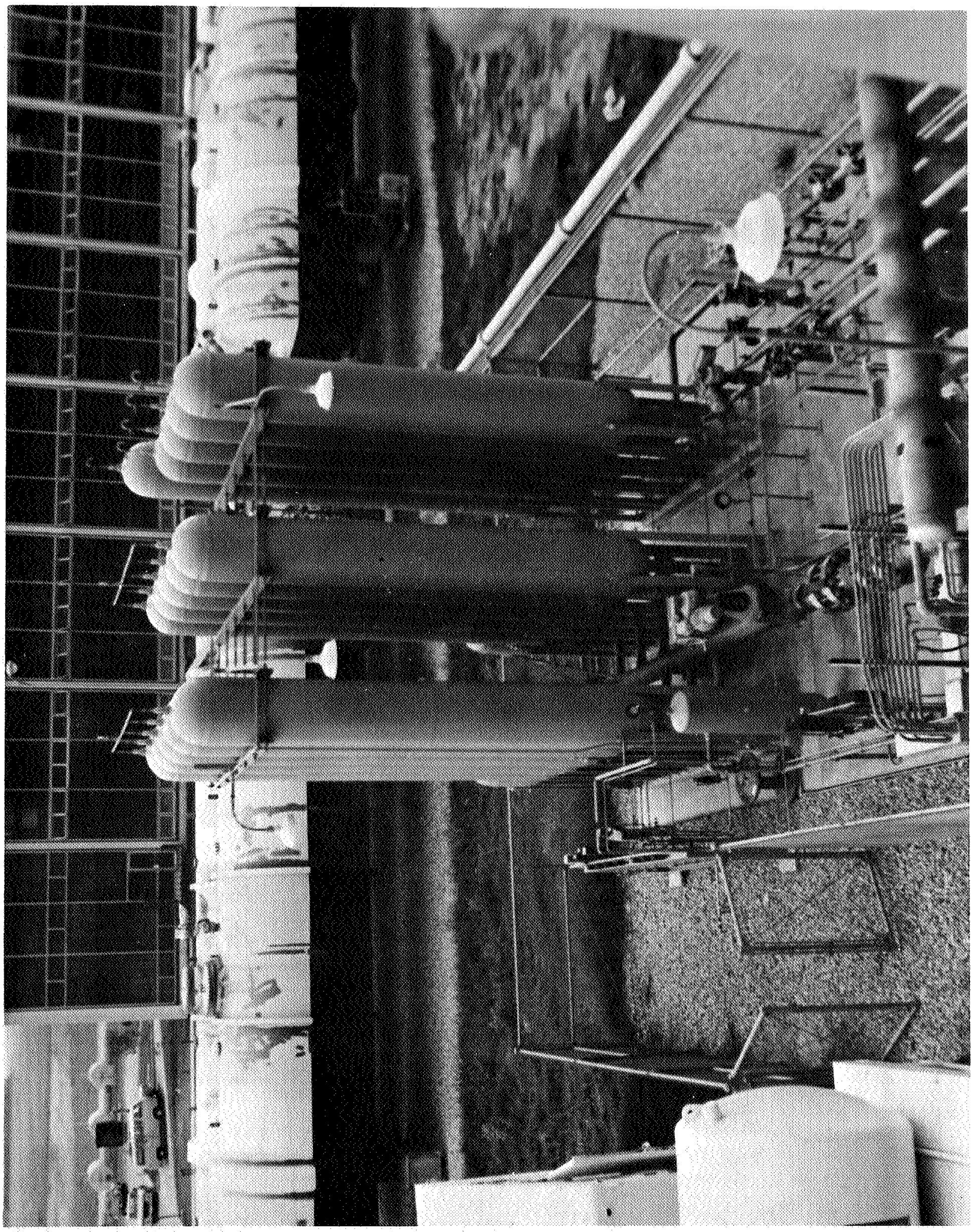

NASA
S-65-44002

APPENDIX E

1. Suggested lesson plan guide accompanied by notations to the instructor(s)

2. Suggested session quiz and related answer sheet

3. Selected support materials, including opaque projection materials, "Some Cryogenic Highlights," "Some General Cryogenic Safety Precautions," and transparencies

Suggested Lesson Outline

for

Session 5

INTRODUCTION TO CRYOGENICS

AND

LIQUID OXYGEN

Estimated Time	Item(s)
	1.0 Session introduction
	1.1 Project transparency S-67-457 and discuss the session objectives.
	1.2 Use transparency S-67-96 to define the term "cryogenics," stressing the fact that this is but one of the currently accepted definitions of this term.
	1.3 Present a report or have the class members report on the emergence of this rapidly growing field for approximately 5 minutes.
0015	1.4 Discuss briefly the role of cryogenics in manned space flight, giving examples of its use at this Center such as the Space Environmental Simulation Laboratory (SESL).
	2.0 Role of materials in cryogenics field
	2.1 Use the comparative temperature scale transparency S-67-4616 (K, F, C, and R) to show where "cryogenics" starts on each scale. Stress the fact that C and K scales are most commonly used at MSC.
	2.2 Use transparencies S-67-151 and S-67-462 to show how the normal boiling points of cryogens compare.
	2.3 Point out the functional aspects of ultralow temperatures and enumerate the following on the chalkboard.

Estimated Time	Item(s)
	a. Superconductivity
	b. Superfluidity
	c. High vacuum insulation, and so forth
	d. Definition of items a to c
	2.4 Also, discuss aspects of "Some Cryogenic Highlights" (appendix E).
	2.5 Show the display of materials being used with cryogenic fluids.
	(a) Metals such as titanium, magnesium, tantalum, alloy steels, and so forth.
	(b) Nonmetals such as glass insulating materials (vacuum); paper; fine powders such as silica aerogel, perlite, and calcium silicate; rigid forms, including polystyrene; polyurethane; rubber; silica; plastics (fluorocarbons); elastomers (in static seals); and so forth.
0035	2.6 Show the opaque projection views of metallic and nonmetallic materials used with cryogenic materials by showing S-67-36439 and S-67-36449. (optional)
	3.0 Cryogenic liquids used at Center
	3.1 Use the opaque projector (or chalkboard) to show "Locations and Types of Cryogenic Liquids Used at the Manned Spacecraft Center." (appendix E)
0040	3.2 Discuss the purposes for which cryogenic liquids are used using S-67-20407, aerial view of Center, as a supplementary aid.
	4.0 General safety precautions for handling cryogenic materials
0045	4.1 Use the chalkboard for presentation of "Some General Cryogenic Safety Precautions" (appendix E).

Estimated Time	Item(s)
	5.0 Project announcement
	5.1 Announce to the class that each participant will have an opportunity to design a system within the next several days, treating such items as design, testing, cleaning of storage tanks, activation of storage tanks, and required safety features.
	5.2 Display transparency S-67-152 as an example of a system and discuss it in relation to section 5.1.
0055	5.3 Announce that each class participant will be allowed class time to work on this project, a project which will be turned in prior to the commencement of session 9.
0105	C L A S S B R E A K
	6.0 Properties, characteristics, and related aspects of LOX
	6.1 Review briefly the properties of air by quickly covering charts S-67-35693 and S-67-35694 on "air."
	6.2 Project transparency S-67-98 to discuss properties and characteristics of LOX.
	6.3 Introduce the film entitled "Liquid Oxygen — Safe Handling and Storage," which treats the characteristics, safe handling, transfer, and storage procedures for LOX.
	6.4 Present the aforementioned film.
	6.5 Have the class members summarize the film highlights.
	6.6 Summarize the film using, in part, transparency S-67-152 for transfer and storage.
	6.7 Discuss briefly LOX spills, leaks, and decontamination.

Estimated Time	Item(s)
0130	6.8 Mention shipping and storage, pointing out that both topics will be discussed in greater detail later during the course.
	7.0 LOX safety and handling measures
	7.1 Present the safety and handling measures concerned with LOX through the use of transparency S-67-90. (Stress the utilization of protective clothing.)
	7.2 Show transparency S-67-4355 on LOX fire and exposure hazards.
	7.3 Follow up the presentation of item 7.2 by discussing what to do in case of LOX accidents, using transparency S-67-4350 to advantage.
	7.4 Familiarize the class with LOX safety procedures in MSC Safety Manual (MSCM 1700), Part 5, Subpart 9.
0140	7.5 Phase this section out with the showing of cartoon S-67-156.
	8.0 Session assessment
	8.1 Administer the quiz.
0150	8.2 Discuss the quiz items.
	9.0 Summary and distribution of materials
	9.1 Summarize the session and announce the topics for the next session.
0200	9.2 Distribute the handout items.

Notations to the Instructor

1. Organize the aids such as films, opaque projection materials, and so forth and carefully preview each prior to class.

2. Review the articles and other reference material prior to class.

3. Try to draw from the class the different site locations and utilization of LOX at the Center.

4. Arrange for a classroom display of equipment materials used in cryogenics.

5. Prepare for distribution of the handout items for this session.

6. Update the chart entitled "Locations and Types of Cryogenic Materials used at the Manned Spacecraft Center" just prior to each course presentation.

7. For purposes of this course, it is recommended that only the first section of film MN-8364B (through the "Transfer and Storage" part) be shown.

APPENDIX E

Some Cryogenics Highlights[4]

The study, development, and improvement of extremely low temperature processes, techniques, and equipment, is known as cryogenics (cry-oh-jenn-icks). Cryogenic temperatures range downward from -130° C (-270° F) to nearly absolute zero, -273° C (-460° F). The term "cryogenics" stems from the Greek word "kryos," which means icy cold.

Since the 1870's, when extremely low temperatures were first produced by making liquid air, many important advances have been made, including the discovery of superconductivity, which can be lost if the metal or alloy concerned is exposed to a magnetic field.

There is more than adequate reason for treating cryogenics as a special field. The physical properties of materials at very low temperatures differ substantially from those ordinarily encountered, thereby making normal experience with materials unreliable and invalid. The following examples illustrate this point.

1. The heats of vaporization of low-boiling liquids are quite small. Therefore, such liquids can be preserved only in very well insulated storage vessels. (It should be mentioned that the heat of vaporization is so small in the case of liquid helium that it has very little cooling power.)

2. Certain materials become very brittle at low temperatures. Carbon steel is a good example of this, exemplified by disastrous failures in engineering structures. However, many nonferrous metals and alloys such as aluminum, copper, nickel, and stainless steel behave well at low temperatures.

3. At low temperatures, the electrical resistances of pure metals are extremely small. Some metals have "zero" resistance below a certain temperature. This phenomenon is known as superconductivity.

4. With decreasing temperatures, the specific heats of all liquids and solids decrease. The specific heats of solid and liquid matter become exceedingly small at very low temperatures.

5. The thermal conductivity of most pure metals and monocrystalline solids increases substantially at low temperatures. These same metals and solids have a maximum value which greatly exceeds that of room temperature. On the other hand, most alloys exhibit a progressive decrease in thermal

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[4]Bulk of material from: Russell B. Scott, Cryogenic Engineering. Chapter I, Introduction, D. Van Nostrand Co., Inc., 1959, Reprinted November 1963, pp. 1-4.

conductivity with decreasing temperature. (The thermal conductivity of alloy materials approaches zero as "absolute zero" in degrees is approached.)

6. <u>Proper insulation is of the utmost importance when low temperature apparatus and equipment are involved</u>. Since one of the best insulators is a vacuum, high-vacuum techniques are of great importance in low-temperature technology.

7. <u>When utilizing a high vacuum for insulation purposes, it frequently happens that nearly all of the residual heat transfer is by thermal radiation across the insulating vacuum</u>. Consequently, the study and control of energy transfer by radiation is very important to those concerned with cryogenics.

In the development of rocket fuels and in the manufacture of steel, cryogenics has proven very valuable. Cryogenics is being used to develop superconductivity bearings with greatly reduced friction, electric motors with high efficiency, and powerful magnetic lenses for electron microscopes. Moreover, cryogenics has contributed to the production of sensitive electronics amplifiers and the creation of high-magnetic fields for thermonuclear reactors. Cryogenics is also being used in the separation of gases and to an increasingly greater extent, at the Manned Spacecraft Center.

The cryogenic gases whose properties will receive the most attention in this course are oxygen, nitrogen, hydrogen, helium, and several of the rare gases.

Suggested Session 5 Quiz

INTRODUCTION TO CRYOGENICS

and

LIQUID OXYGEN

A. Matching

Column A has five definitions. Column B has 10 cryogenic terms. Match the correct definition in column A with its proper corresponding cryogenic term in column B. In the blank space preceding each definition, place the corresponding and correct term found in column B.

	Column A	Column B
______	A. Surrounding or encircling	1. Superconductivity
______	B. To make impure or unclean by coming in contact with something	2. Corrosive
		3. Contaminate
______	C. Type of vacuum insulated double walled storage bottle and/or tank	4. Specific heat ratio
		5. Cryogenics
______	D. The phenomenon by which some substances suddenly lose all electrical resistance when their temperatures are reduced below that of liquid hydrogen	6. Oxidizer
		7. Triple point
		8. Dewar vessel
______	E. Ultralow temperature science and technology	9. Ambient
		10. Thermal conductivity

B. Multiple Choice

1. Which of the following properties do not pertain to LOX?

   a. Boils at -452° F
   b. Can detonate powdered organic materials
   c. Nontoxic
   d. Causes organic materials to react violently when ignited
   e. Can produce large volumes of gaseous oxygen

2. Which of the following best describes the color of LOX?

   a. Transparent
   b. Pale blue

c. Pale green
d. Pale red
e. Pale yellow

3. Which of the following procedures will not be observed in LOX fire-fighting procedures?

   a. Remove everyone not actively engaged in fighting the fire.

   b. Shut off the flow of oxygen, if possible.

   c. Use large quantities of water in spray form to cool the burning material below the ignition point.

   d. Use CO_2, dry chemical, or vaporizing liquid extinguishers rather than water if electrical equipment is involved in the fire.

   e. Use foam extinguishers.

4. Which of the following is untrue about LOX storage?

   a. It should be stored in double-wall stainless steel tanks.

   b. It should be placed in vacuum tanks protected by insulation from heat transfer.

   c. It should be placed in an area kept clear of fire hazards.

   d. Relief valves and burst diaphragms should be removed from the storage tank piping system.

   e. Vented gases should be kept away from personnel and combustible materials.

5. Protective clothing required for handling LOX includes all but which of these articles?

   a. Face shields
   b. Rubber gloves
   c. Life line and air mask for work inside a tank
   d. Rubber or asbestos hat
   e. Rubber boots

C. True and False

_____ 1. One objective of the MSC Space Environmental Simulator Laboratory (SESL) is to conduct operational tests of Apollo and other spacecraft systems and components.

_____ 2. Another objective of SESL is to test, develop, and evaluate the capability of man to perform useful functions inside and outside spacecraft on a simulated lunar surface.

_____ 3. The normal boiling point of LOX is -297.33° K.

_____ 4. Materials which burn in air usually burn much more slowly in oxygen.

_____ 5. LOX is transferred and stored as a liquefied compressed gas and must be stored in fixed or mobile containers of approved design, materials, and construction.

Session 5 Quiz Answers

A. Matching

1. Ambient
2. Contaminate
3. Dewar vessel
4. Superconductivity
5. Cryogenics

B. Multiple Choice

1. A
2. B
3. E
4. D
5. D

C. True and False

1. True
2. True
3. False
4. False
5. True

APPENDIX E

Some General Cryogenic Safety Precautions

Under different conditions of temperature and pressure, nitrogen, oxygen, argon, neon, and others become liquids. Though these liquids have different properties, potential hazards emanate from two properties they have in common — their coldness and their rapid expansion when converted from liquid to gaseous states. For example, 1 cubic foot of LOX converts to 799 cubic feet of gas. Therefore, for safety reasons the following rules should be observed.

1. Avoid contact with these ultra-cold liquids, and the pipes and vessels which contain them.

2. Wear proper protective clothing for protection of head, body, and extremities.

3. Handle liquids in well-ventilated areas to prevent excessive concentrations of gas.

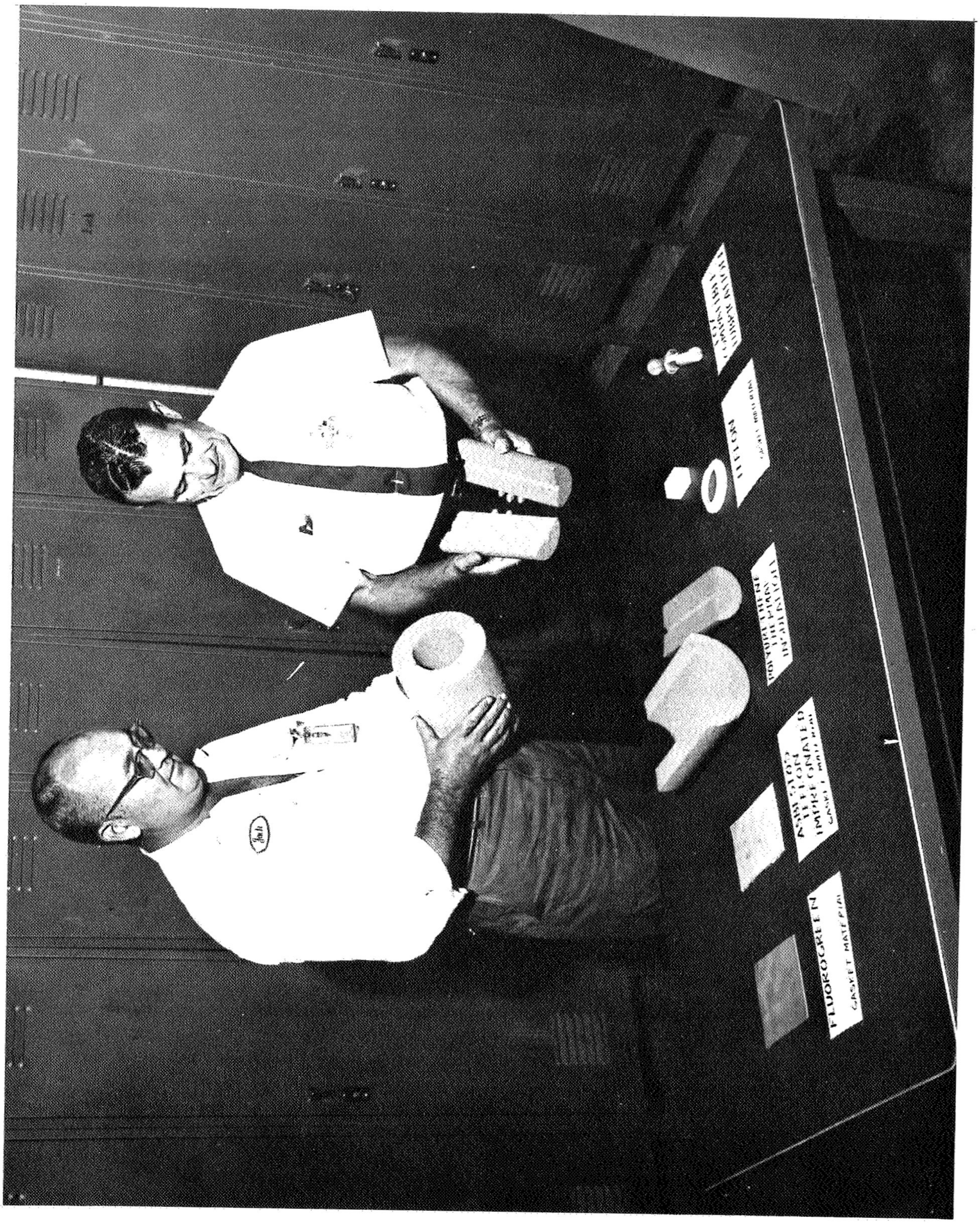
4. Use only those containers especially designed and approved in-service for cryogens.

5. Use containers only with the liquids for which they were specifically designed and approved.

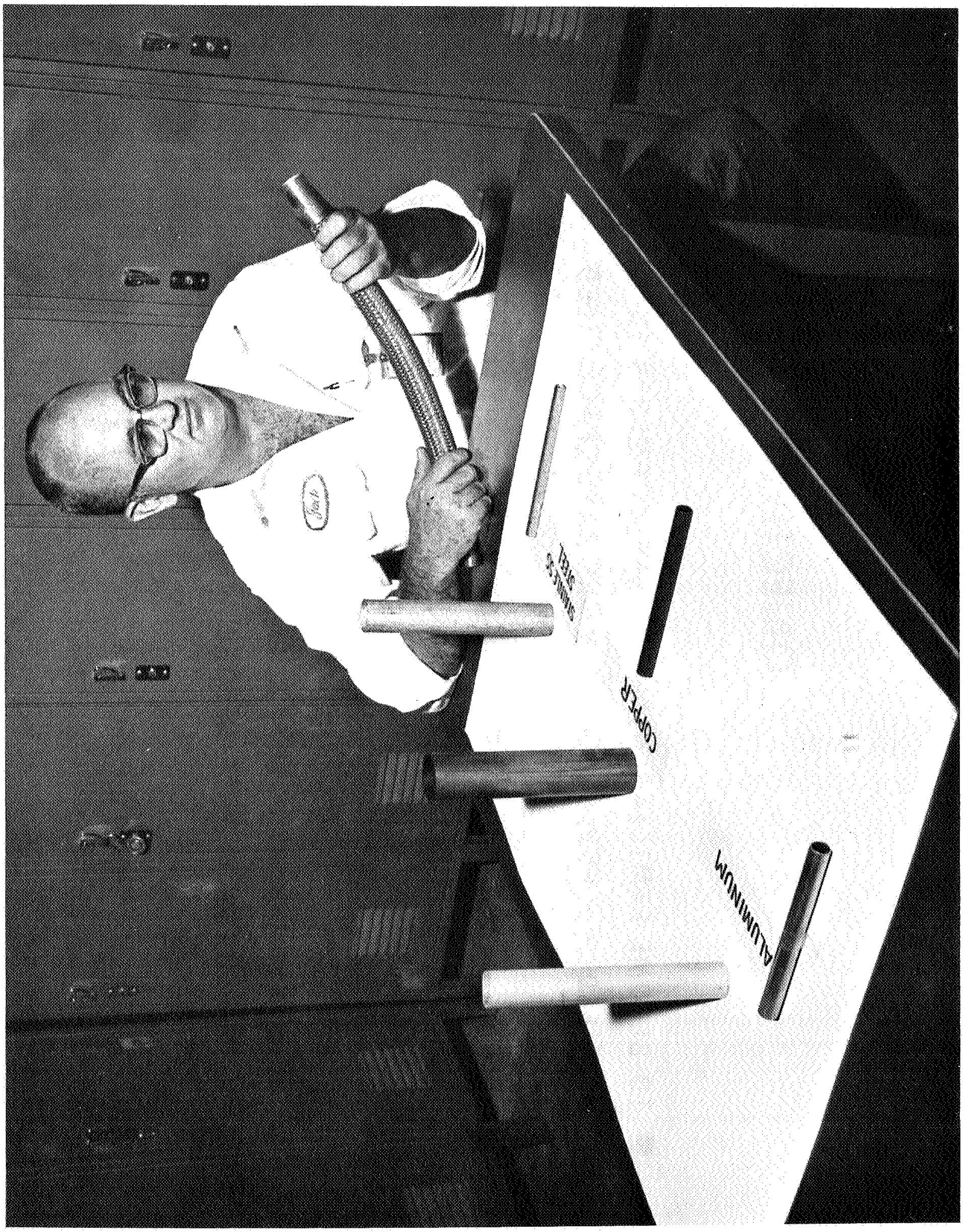
6. Use only the approved transfer equipment.

7. Obtain competent advice before installing or maintaining cryogenic equipment or piping and then follow prescribed procedures for operating and maintaining such equipment.

8. Ascertain that only properly trained and authorized personnel have access to liquid storage areas.



NASA
S-67-36439



NASA
S-67-36449

NASA-S-67-457

OBJECTIVES

- TO BECOME FAMILIAR WITH THE DEVELOPMENTS IN THE CRYOGENICS FIELD - - ESPECIALLY, IN THE AEROSPACE FIELD
- TO BECOME ACQUAINTED WITH CRYOGENIC MATERIALS - - PARTICULARLY, LIQUIDS AT THIS CENTER
- TO PROVIDE A THOROUGH UNDERSTANDING FOR THE NEED AND IMPLEMENTATION OF CRYOGENIC SAFETY PRECAUTIONS AND MEASURES AT THIS CENTER
- TO BECOME FAMILIAR WITH A TYPICAL CRYOGENIC LIQUID-LOX

NASA-S-67-96

CRYOGENICS

THE SCIENCE THAT DEALS WITH THE PRODUCTION OF VERY LOW TEMPERATURES (USUALLY BELOW - 150°F) AND THEIR EFFECT ON THE PROPERTIES OF MATTER

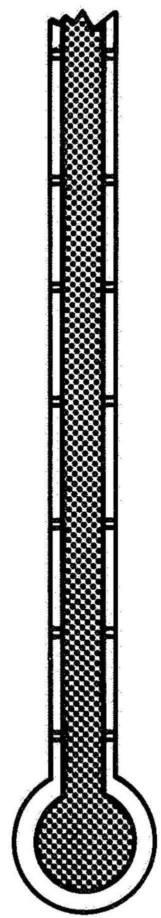
ALSO, THIS SCIENTIFIC FIELD IS CONCERNED WITH THE PRACTICAL APPLICATION OF VERY LOW-TEMPERATURE PROCESSES AND TECHNIQUES

NASA-S-67-462

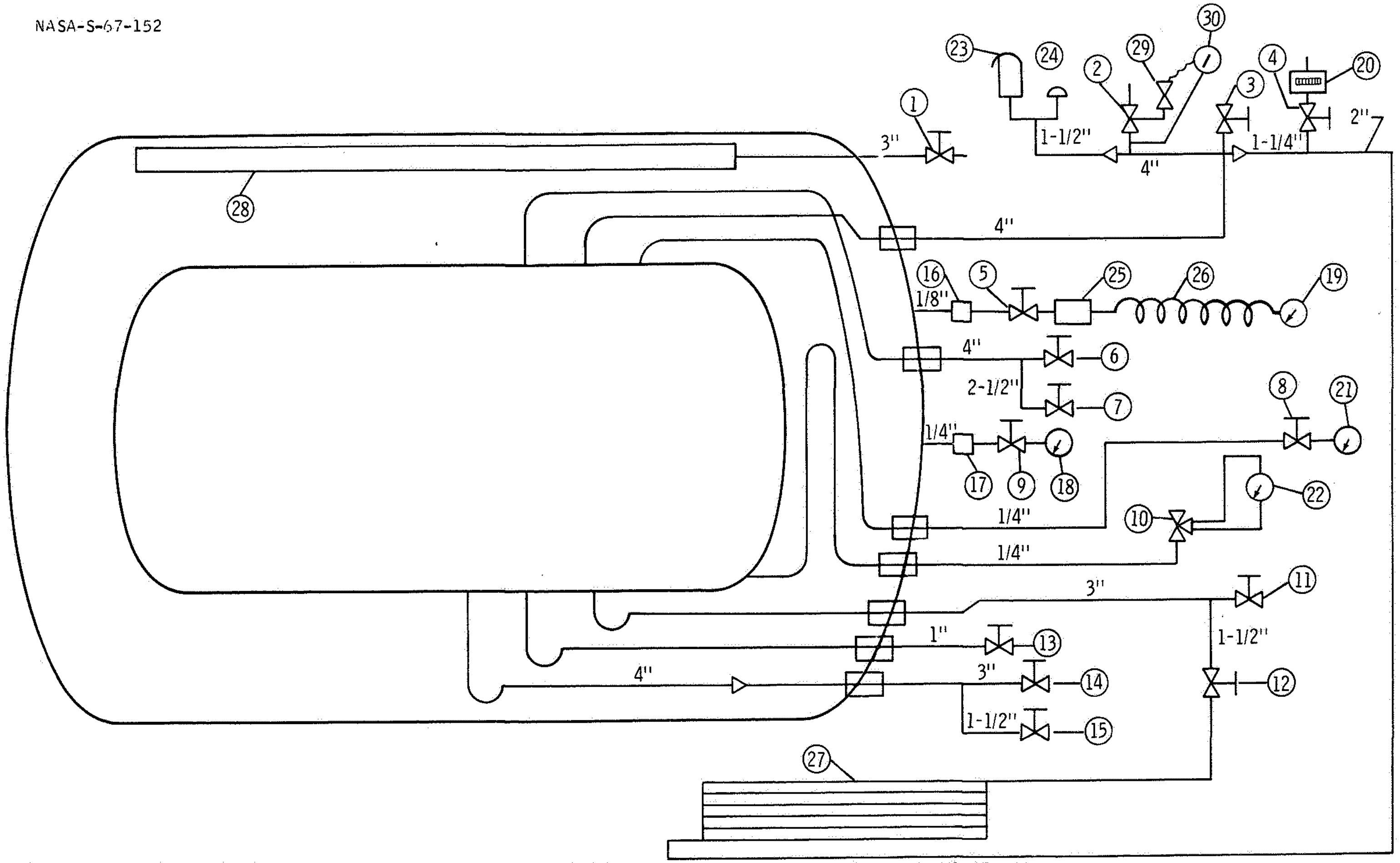
CRYOGENIC THERMOMETER

NORMAL BOILING POINTS OF CRYOGENIC FLUIDS

		DEGREES F
KRYPTON	LKr	-243.8
OXYGEN	LOX	-297.33
ARGON	LAr	-302.55
FLUORINE	LF_2	-306.6
NITROGEN	LN_2	-320.36
NEON	LNe	-410.8
HYDROGEN	LH_2	-423.0
HELIUM	LHe	-452.1
ABSOLUTE ZERO		-459.69



NASA-S-67-152



ITEM	DESCRIPTION	ITEM	DESCRIPTION	ITEM	DESCRIPTION
1.	4" VACUUM VALVE	11.	3" DRAIN VALVE	21.	PRESSURE GAUGE
2.	4" VENT VALVE (3 PNEUMATIC ACTIVATED)	12.	1-1/2" PRESSURIZING VALVE	22.	L L GAUGE
3.	4" VENT VALVE	13.	1" AUXILIARY TRANSFER VALVE	23.	1-1/2" SAFETY VALVE
4.	1-1/4" FLOW METER VALVE	14.	3" TRANSFER VALVE	24.	1-1/2" REPTURE DISC.
5.	1/8" FINE VACUUM VALVE	15.	1-1/2" AUXILIARY TRANSFER VALVE	25.	THERMOCOUPLE GAUGE TUBE
6.	4" FILL VALVE	16.	MICRON FILTER	26.	COMPENSATION CORD
7.	2-1/2" AUXILIARY FILL VALVE	17.	MICRON FILTER	27.	PRESSURIZING COIL
8.	1/4" PRESS. GA. VALVE	18.	ROUGH VACUUM GAUGE	28.	VACUUM LINE FILTER
9.	1/4" ROUGH VACUUM VALVE	19.	FINE VACUUM GAUGE	29.	1/4" SOLENOID VALVE
10.	1/4" NPT L L ISOLATION VALVE 3-WAY DEMI-34)	20.	FLOW METER	30.	MERCOID SWITCH

NASA-S-67-98

LIQUID OXYGEN
PROPERTIES AND CHARACTERISTICS

- MINUS 297° F
- PALE BLUE
- NON-TOXIC
- CAUSES ORGANIC MATERIALS TO REACT VIOLENTLY WHEN IGNITED
- CAN DETONATE POWDERED ORGANIC MATERIALS
- PRODUCES LARGE VOLUMES OF GASEOUS OXYGEN

NASA-S-67-90

OXYGEN
SAFETY AND HANDLING

- AVOID CONTACT
- USE PROPER STORAGE AND HANDLING EQUIPMENT
- PROVIDE ADEQUATE VENTILATION
- PREVENT SOURCES OF IGNITION
- OBTAIN A THOROUGH KNOWLEDGE OF THIS ELEMENT BEFORE WORKING WITH IT

LOX

(—297°F OR 90°K)
(COLD AND ODORLESS)

MAJOR HAZARDS

- FIRE

  REMEMBER THAT MIXTURES WITH FUELS IGNITE READILY AND MAY EVEN EXPLODE. MATERIALS WHICH BURN IN AIR USUALLY BURN MUCH FASTER IN OXYGEN; MATERIALS WHICH DO NOT NORMALLY BURN IN AIR MAY BURN IN OXYGEN.

- EXPOSURE

  COLD GAS OR LIQUID MAY CAUSE SKIN AND EYE INJURIES SIMILAR TO BURNS.

NASA-S-67-4350

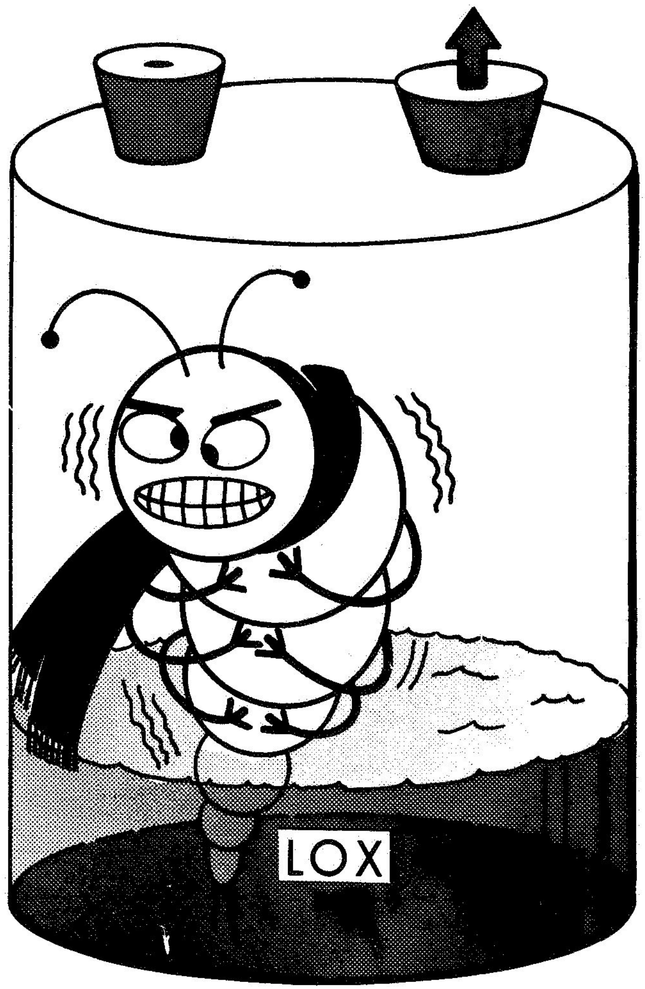
LOX

IN CASE OF ACCIDENT

IF THIS OCCURS 	DO THIS 
SPILL OR LEAK	SHUT OFF IGNITION SOURCE(S). SMOKING OR USE OF FLARES IS <u>NOT</u> PERMITTED. KEEP UNNECESSARY PERSONNEL AWAY FROM AREA. DO <u>NOT</u> WALK ON OR ROLL EQUIPMENT OVER SPILL AREA UNTIL FROST HAS DISAPPEARED. USE PROPER CLOTHING (GLOVES, FACE SHIELD, ETC.) TO ENTER SPILL AREA. SHUT OFF SOURCE(S) OF SUPPLY BY USING PROPER EQUIPMENT. CONDENSED MOISTURE (FOG) USUALLY INDICATES WATER VAPOR.
FIRE	USE WATER TO SPRAY TANK THAT IS EXPOSED TO FIRE. IF SUBSTANTIAL PARTS OF INSULATION JACKET AND INSULATION ARE GONE, VACATE GENERAL AREA.
EXPOSURE	THAW FROSTED PARTS WITH WATER. GET PROMPT MEDICAL ATTENTION. AIR CLOTHING THOROUGHLY FOR 30-60 MINUTES BEFORE SMOKING OR APPROACHING ANY SOURCE OF IGNITION.

NASA-S-67-156

LEAVE AN OPENING TO PREVENT EXCESSIVE PRESSURE



APPENDIX F

1. Suggested lesson plan guide accompanied by notations to the instructor(s)

2. Suggested session quiz and related answer sheet

3. Selected support materials, including opaque projection materials, the poem, "LOX-LN_2 Production," and transparencies

Lesson Plan

for

Session 6

LIQUID NITROGEN AND RELATED ASPECTS

Estimated Time	Item(s)
	1.0 Review and session introduction
	1.1 Inform the class that this session on LN_2 is an extension, in part, of the material which was covered during the previous session.
0010	1.2 Discuss following session objectives using the chalkboard, transparency, or "flip chart" as appropriate.
	a. To gain awareness of the general properties and characteristics of LN_2
	b. To become familiar with the hazards, safety procedures, and special protective clothing associated with handling LN_2
	c. To demonstrate the effects of liquid nitrogen on various materials
	d. To develop an awareness of the methods of manufacture and production of LOX and LN_2
	2.0 Production of oxygen and nitrogen
	2.1 Introduce the film, "Oxygen-Nitrogen Generating Plant."
	2.2 Show the film.
	2.3 Conduct a postfilm screening by reviewing transparencies S-67-153 and S-67-157, and introducing air separation.
0025	2.4 Present the poem, "LOX-LN_2 Production."

Estimated Time	Item(s)

3.0 Liquid nitrogen

3.1 Demonstrate, while wearing appropriate safety clothing, the effect that LN_2 has on various materials such as rubber, vegetable matter, a lubricant, alcohol, and a ball. Have several class members, wearing appropriate protective clothing, participate in the demonstration.

3.2 Project transparency S-67-99 to show the properties and characteristics of LN_2.

3.3 Have class members compare LN_2 characteristics with those of LOX.

3.4 Differentiate between the production of LN_2 and LOX.

4.0 Hazards and safety measures

4.1 Use transparency S-67-90 and compare the precautions for LN_2 with those required for LOX.

4.2 Show transparency S-67-161 and point out the application of the "CAUTION" safety sign used at MSC, such as the sign shown on the trailer.

4.3 Display transparency S-67-159 and show the cryogenic identification standard for LN_2 which appears in Part 6, Subpart 3, of the MSC Safety Manual (MSCM 1700)

4.4 Point out in item 4.3 that different size trailers have different requirements for sign size, panels, safety warning term, and space for working beneath the panel. (Remind the class members to use Part 6, Subpart 3, of the MSC Safety Manual as a guide.)

4.5 Display transparency S-67-160 which shows the "DANGER" safety sign for LOX displayed properly at the Center. (Also, call the attention of the class to the "CAUTION" warning in the same picture.)

Estimated Time	Item(s)
0040	4.6 Just as in item 4.2 pertaining to "CAUTION," show transparency S-67-158. Discuss with the class the various cryogenic identification standards for LOX. Stress use of Part 6, Subpart 3, of the MSC Safety Manual (MSCM 1700) for guidance purposes in the area of these standards and their identification.
	5.0 Materials and equipment used with LN_2
	5.1 Give examples of metals, nonmetals, and lubricants being used with both LOX and LN_2.
0050	5.2 Display as appropriate: equipment items used with LN_2 for cleaning, containers, pipes, fittings, gaskets, valves, high-pressure pumps, vaporizers, and gages.
0105	C L A S S B R E A K
	6.0 LN_2 storage criteria
	6.1 Discuss main storage, receiving, ready storage, and shipping.
0125	6.2 Discuss and explain the following subjects. a. Construction, diking, electrical equipment, access roads, safety equipment, drainage, ventilation, housekeeping, and so forth b. Role of tanks, trucks, containers, cylinders, and so forth
	7.0 Spills, leaks, and decontamination
	7.1 Compare the handling of LN_2 spill leaks and decontamination with that of LOX.
0135	7.2 Discuss the mass spillage effect of LOX when water is used.

Estimated Time	Item(s)
	8.0 Typical LN_2 systems associated with space chambers
	8.1 Discuss storage tank transfer to or from the charging station.
	8.2 Explain operation of the LN_2 system.
0145	8.3 Discuss the following system functions.

a. Primary — heat sink (to absorb reflected solar energy)

b. Secondary — cryopumping (wherein LN_2 temperatures shield the panels and helium cryopumping system temperatures assist the vacuum system by condensing residual gases)

9.0 System safety

9.1 Discuss the need for adequate relief valves and burst disks.

9.2 State the purpose of extended stem valves and relief valve extensions in cryogenic systems.

9.3 Explain venting and its relationship to the magnitude of the system under the following conditions.

a. In a confined ventilation system

b. In a closed ventilation system

WARNING

The Maximum amount of gas vented from an LN_2 system into a confined area cannot exceed the volume of the space concerned.

0155 — 9.4 Concentrate the aforementioned items with requirements at the Manned Spacecraft Center for Life Support Systems.

Estimated Time	Item(s)
	10.0 Session assessment
	10.1 Administer the quiz.
	10.2 Discuss the quiz items.
	11.0 Summary and distribution of materials
	11.1 Summarize the session and announce the topic(s) for the next session.
0200	11.2 Distribute the handout items.

Notations to the Instructor

1. Prior to class, make certain that all equipment, materials, and safety considerations are taken care of for the demonstration.

2. Check the curriculum outline to determine the types of handout materials which should be distributed at the end of the session.

3. Set up the 16-millimeter sound motion picture projector and preview film pertaining to the manufacture and production of LOX and LN_2.

4. Set up the overhead transparency projector and appropriate transparencies.

5. Obtain a guest speaker to lecture about a commercial O_2 and N_2 plant for variation of presentation. He should also cover handling, transfer and storage, and safety aspects of O_2 and N_2. (optional)

6. Set up the appropriate equipment and material items for display purposes.

7. Display photographs S-67-17850, S-67-20079, and S-67-36444 on the classroom bulletin board.

APPENDIX F

Suggested Session 6 Quiz

LIQUID NITROGEN AND RELATED ASPECTS

A. True or False

___ 1. Canister-type masks are most effective for protection against asphyxiation by nitrogen and, therefore, should be available for use.

___ 2. Air separation plants commonly in use today produce from 60 to 1000 tons of LOX and LN_2 per 24-hour day.

___ 3. Handlers of LN_2 should protect head and face by wearing acid-type goggles or a face shield.

___ 4. Liquid nitrogen is light blue in color.

___ 5. Liquid nitrogen boils violently when transferred into an uninsulated container at atmospheric conditions.

___ 6. Liquid nitrogen is being increasingly used in food processing plants for quick freezing of fresh vegetables and meats.

___ 7. Interstate Commerce Commission and state regulations prevent suppliers from shipping liquid nitrogen in greater quantities than 2400-gallon trailers over the highways.

___ 8. Mass spillage of LN_2 in a confined area could produce a safety hazard to personnel in the area.

___ 9. Water should be used to treat areas of the skin that come in contact with LN_2.

___ 10. Operations involving the handling of LN_2 should be performed by two or more persons working in groups.

___ 11. Pneumonia may result if an individual breathes pure oxygen for a sustained period of time.

___ 12. At main nitrogen storage sites, an adequate water supply will be provided for flushing, safety showers, and decontamination.

Session 6 Quiz (cont'd)

B. Multiple Choice

___ 1. Liquid air can be made by mixing the liquids in concentrations of approximately ______ and ______.

a. 25 percent oxygen 75 percent helium
b. 20 percent oxygen 80 percent hydrogen
c. 21 percent oxygen 79 percent nitrogen
d. 30 percent oxygen 70 percent argon
e. 23 percent oxygen 71 percent neon

___ 2. What is the normal boiling point of liquid nitrogen at atmospheric conditions?

a. -300° F
b. -422° F
c. -333° F
d. -320° F
e. -297° F

___ 3. Which method generally is used to transfer liquid nitrogen from one storage tank to another with a minimum of loss?

a. Gravity
b. Pressure and gravity
c. Over-pressure
d. Centrifugal pump
e. Positive displacement pump

___ 4. Adequate curbing around LN_2 storage tanks prevents the spread of liquid and vapors. What are the main hazards?

a. Fire and explosion
b. Frostbite and anoxia
c. Frostbite and explosion
d. Fog and freezing
e. Depletion of oxygen and subsequent explosion

___ 5. When LN_2 in a piping system is trapped between two shutoff valves, what should be the recommended protection?

a. Relief valves
b. Check valves
c. Burst disks
d. Relief valves and rupture disks
e. Rupture valves

Session 6 Quiz (cont'd)

C. Completion

1. First and second levels of protection should be provided in LN_2 piping systems and storage vessels by __________ and __________.

2. A dry air mixture can result when liquid __________ and __________ are mixed in proper proportions using vaporizing equipment.

3. The normal boiling point of LN_2 at atmospheric conditions is __________.

4. The insulating space between the inner and outer tanks of LN_2 storage vessel is a combination of __________ and __________.

5. The most common material used for insulating LN_2 hand lines and fuel is __________.

6. In a typical liquid storage tank, the inner vessel is fabricated of __________ steel and the outer vessel utilizes __________ steel.

Session 6 Quiz Answers

A. True and False Answers

1.	False	5.	True	9.	True
2.	True	6.	True	10.	True
3.	True	7.	False	11.	True
4.	False	8.	True	12.	True

B. Multiple Choice Answers

1. c
2. d
3. b
4. b
5. d

C. Completion Answers

1. Relief valves and burst disks
2. Oxygen and nitrogen
3. Minus 320° F
4. Perlite or santocel powder and vacuum
5. Foam polyurethane
6. Stainless, carbon

APPENDIX F

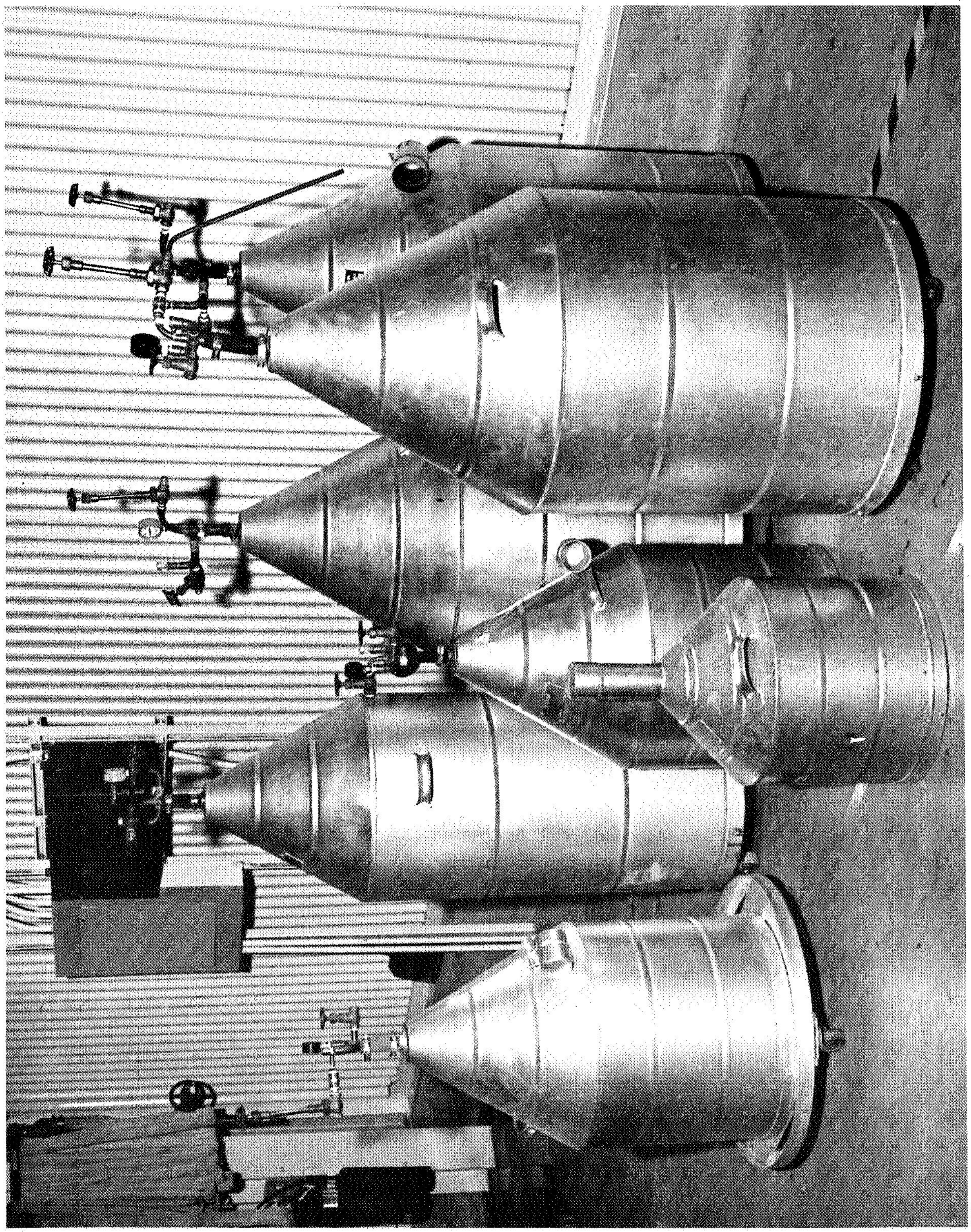
LOX-LN_2 PRODUCTION

THE PRESSURE GOES THE COMPRESSOR UP,
AFTER THIS THE AIR MAKES HOT,
AFTER THE CAUSTIC SCRUBBER GOES,
THE CO_2 IS NOT.

DRIERS NEXT THE WATER CATCH,
THE TEMPERATURE GETS SMALL,
EXPANDING OUTEN BTU,
THE ENTHALPY IS ALL.

THE COLUMNS SPLIT THE MIXTURE,
THE PRESSURE MAKES BY PUMPS,
EXCHANGERS VAPORIZE ALREADY,
OUT YET THE OXYGEN JUMPS.

Donald Stewart
Cryogyne, Inc.
Houston, Texas



NASA
S-67-36444

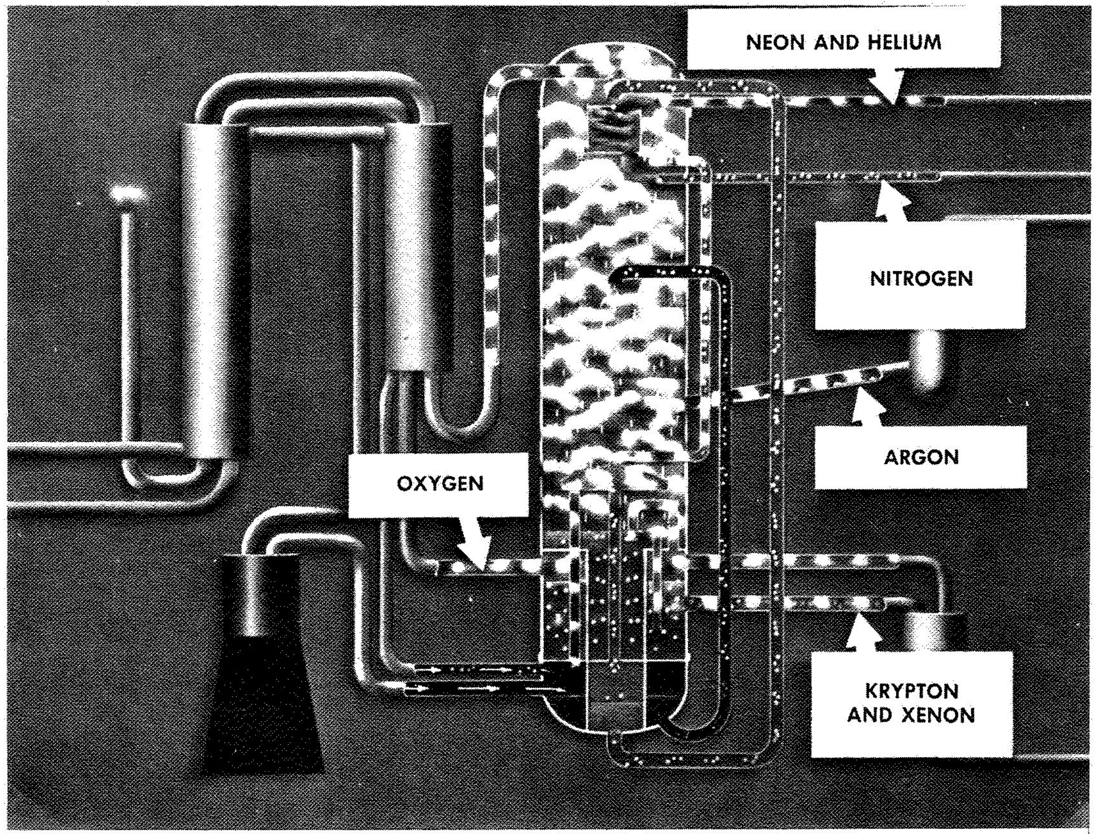
NASA
S-67-20079

NASA
S-67-17850

NASA
S-67-36437

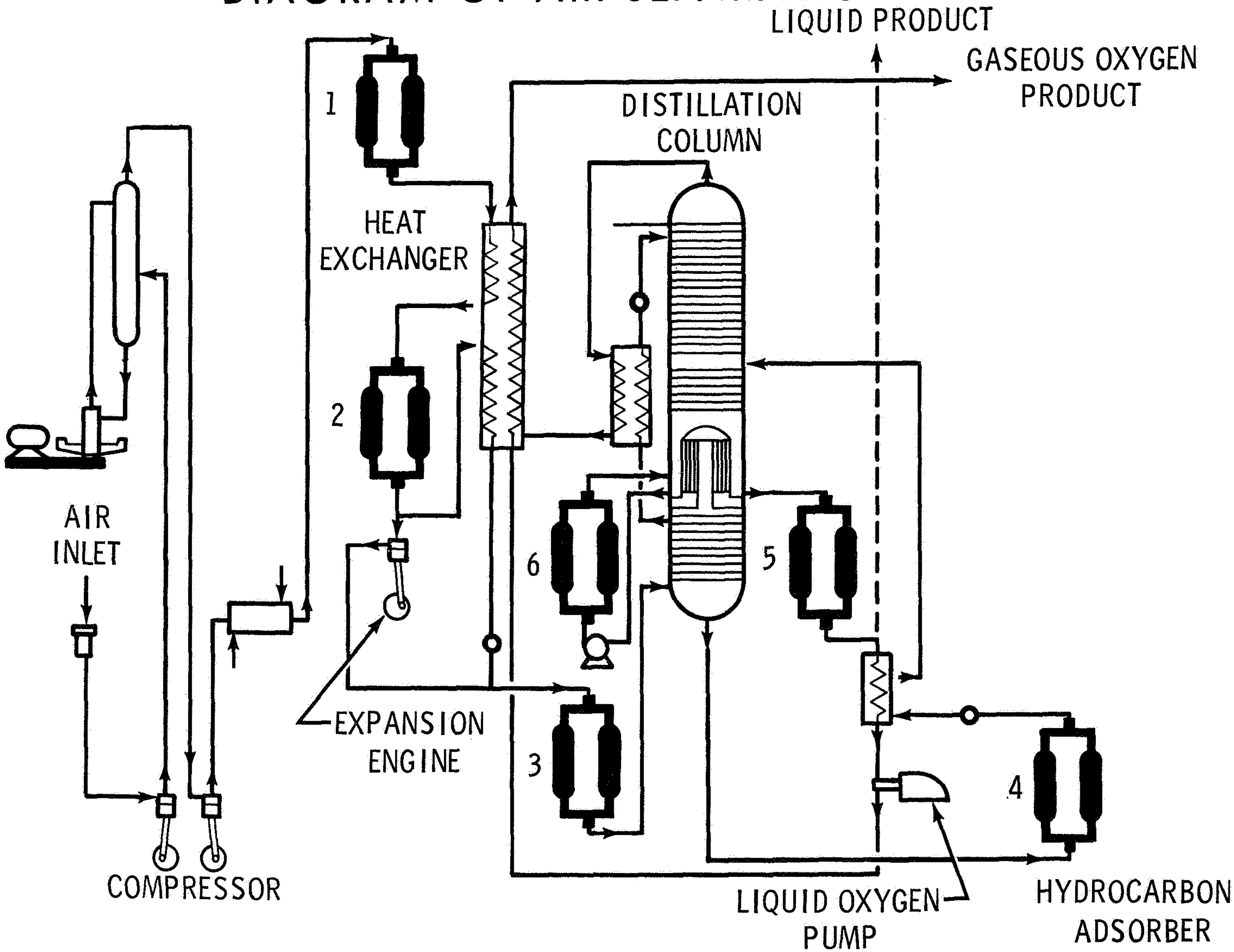
NASA-S-67-153

SEPARATION OF INDUSTRIAL AND RARE GASES FROM THE ATMOSPHERE



NASA-S-67-157

DIAGRAM OF AIR SEPARATION CYCLE

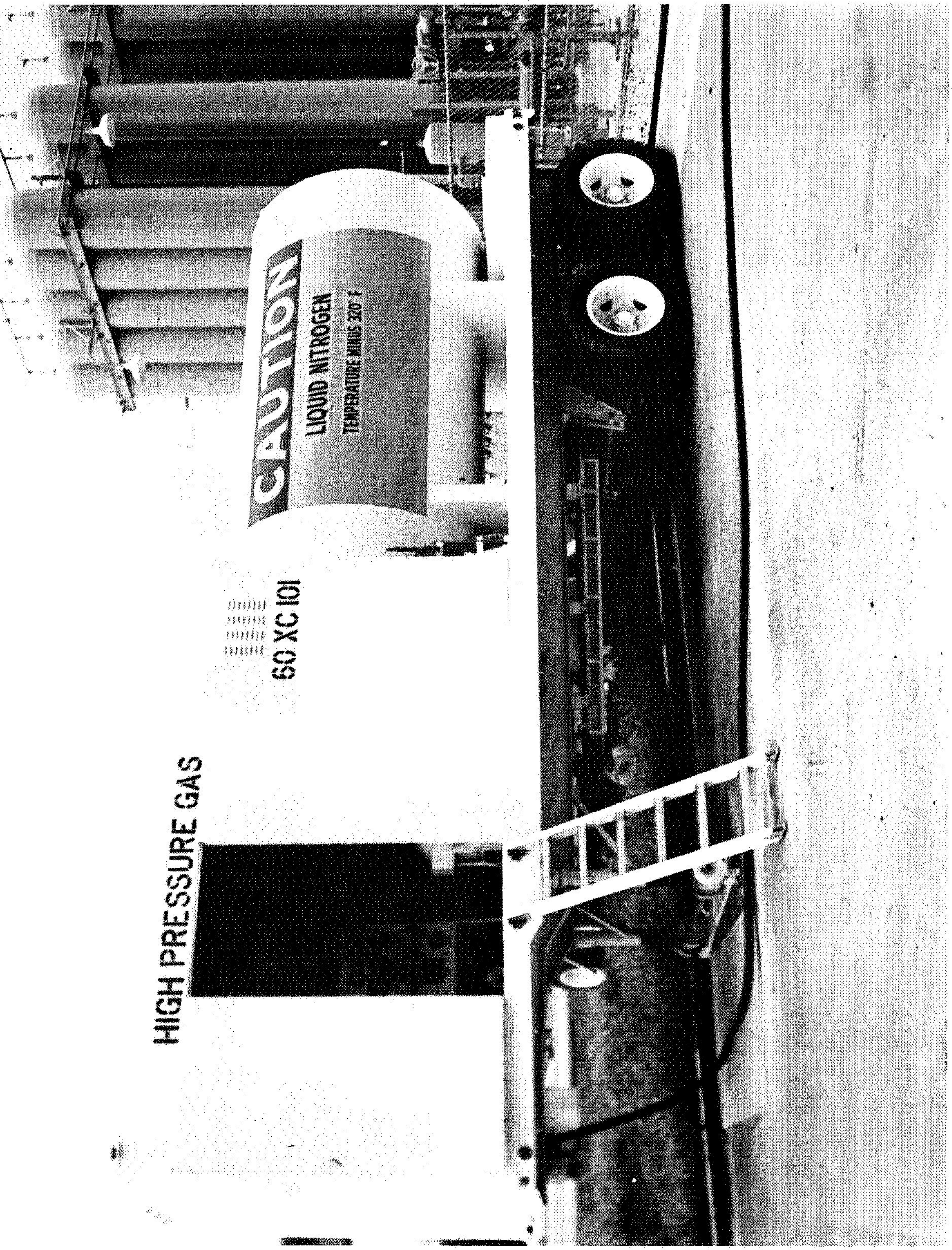


NASA-S-67-99

LIQUID NITROGEN
PROPERTIES AND CHARACTERISTICS

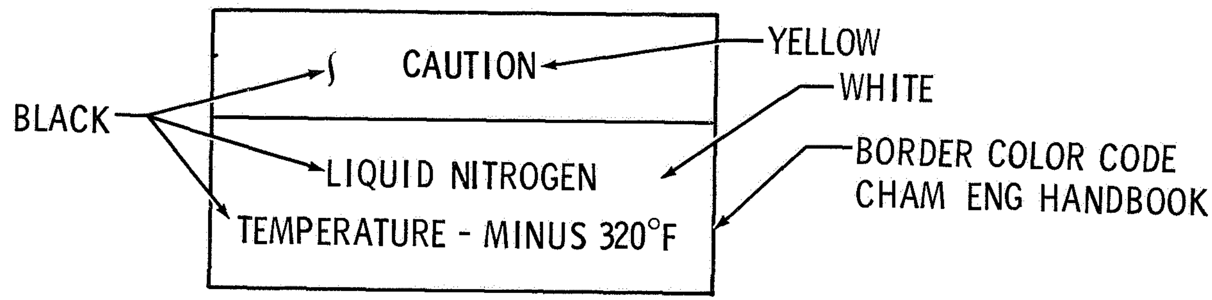
- MINUS 320° F
- TRANSPARENT
- ODORLESS
- NON-CORROSIVE
- NON-COMBUSTIBLE
- EXPANSION RATIO - 695:1

NASA-S-67-161


HIGH PRESSURE GAS
60 XC 101
CAUTION
LIQUID NITROGEN
TEMPERATURE MINUS 320° F

NASA-S-67-159

CRYOGENIC IDENTIFICATION STANDARD FOR LN_2

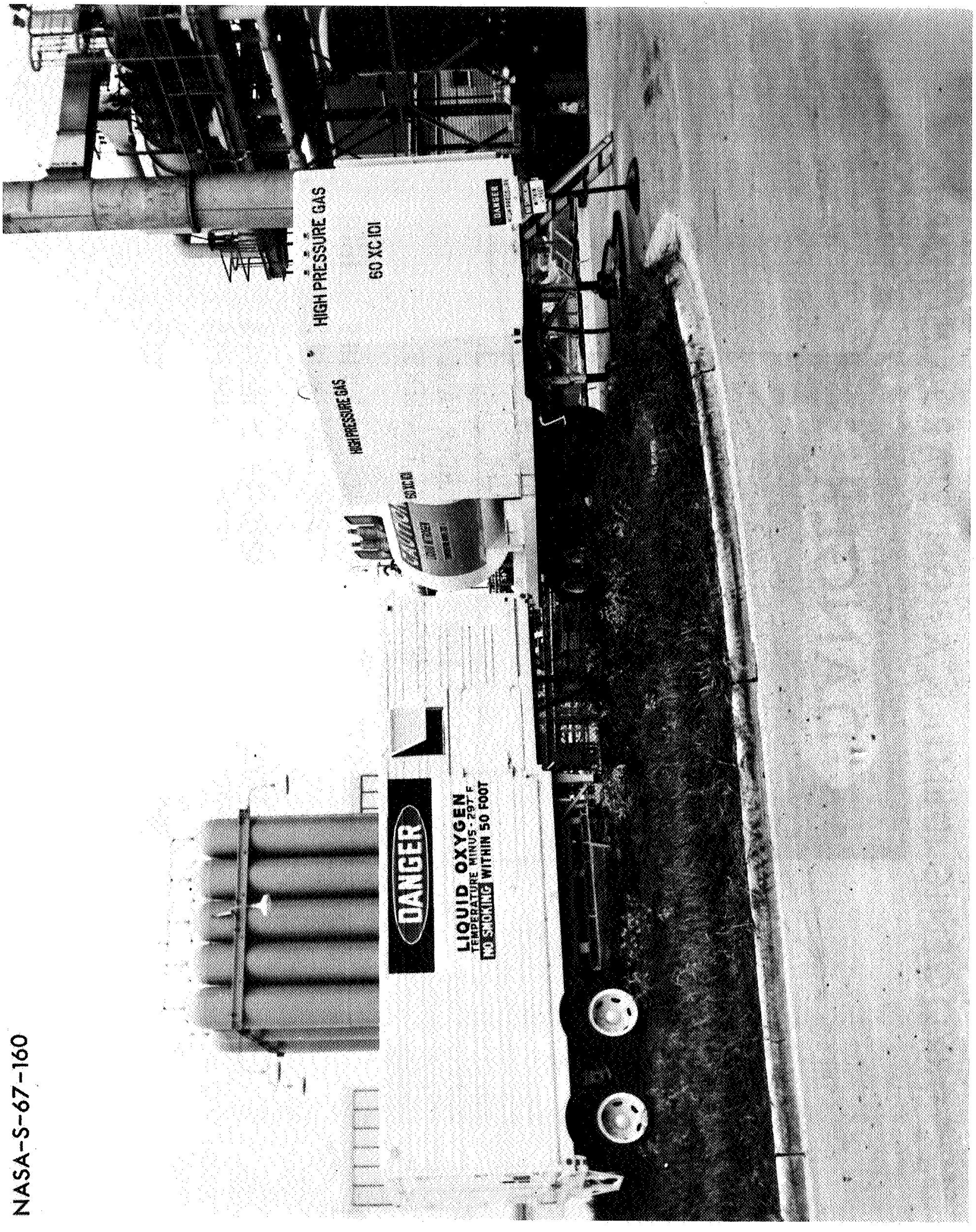


A. SPECIFICATION - 28,000 GAL STORAGE

1. SIGN SIZE — HEIGHT - 110 INCHES; WIDTH - 150 INCHES
2. BLACK RECTANGULAR PANEL — HEIGHT - 24 INCHES; WIDTH - 150 INCHES
3. WORD 'CAUTION' — HEIGHT - 18 INCHES
4. SPACE FOR WORDING BELOW BLACK PANEL - HEIGHT - 86 INCHES; WIDTH - 150 INCHES

B. SPECIFICATION - 4,000 GAL TRAILERS

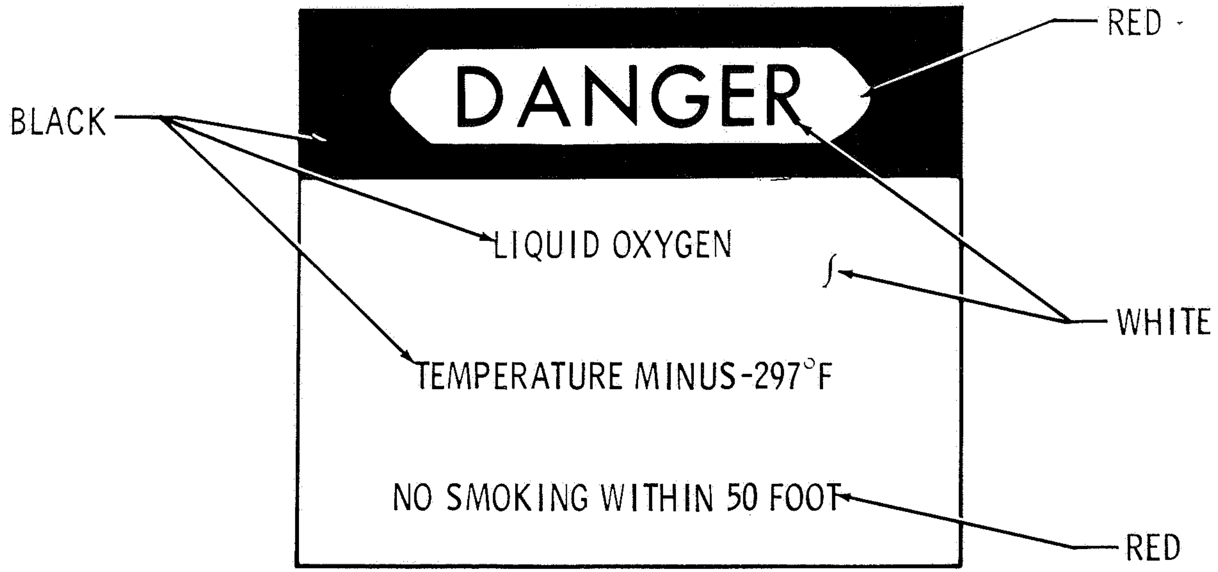
1. SIGN SIZE — HEIGHT - 74 INCHES; WIDTH - 104 INCHES
2. BLACK RECTANGULAR PANEL — HEIGHT - 16 INCHES; WIDTH - 104 INCHES
3. WORD 'CAUTION' — HEIGHT - 12 INCHES
4. SPACE FOR WORDING BELOW BLACK PANEL — HEIGHT - 58 INCHES; WIDTH - 104 INCHES


HIGH PRESSURE GAS
60 XC 101
HIGH PRESSURE GAS
DANGER
LIQUID OXYGEN
TEMPERATURE MINUS -297 F
NO SMOKING WITHIN 50 FOOT

NASA-S-67-160

NASA-S-67-158

CRYOGENIC IDENTIFICATION STARDARD FOR LOX



A. SPECIFICATION- 1800 GAL RECHARGER TANK
- 4000 GAL MOBILE TRAILERS

1. SIGN SIZE	HEIGHT - 74 INCHES	
	WIDTH - 104 INCHES	
2. BLACK RECTANGULAR PANEL	HEIGHT - 16 INCHES	
	WIDTH - 104 INCHES	
3. WORD 'DANGER'	HEIGHT - 12 INCHES	
4. SPACE FOR WORDING BELOW BLACK PANEL	HEIGHT - 58 INCHES	
	WIDTH - 104 INCHES	

NASA-S-67-4353

LN_2

(—320°F OR 77.59°K)

(COLD AND ODORLESS)

MAJOR HAZARDS

- FIRE

  LN_2 IS INERT AND WILL NOT BURN.

- EXPOSURE

  VAPOR IS NOT TOXIC, BUT BREATHING MAY CAUSE SUDDEN UNCONSCIOUSNESS BECAUSE OF LACK OF OXYGEN. COLD GAS OR LIQUID MAY CAUSE SKIN AND EYE INJURIES SIMILAR TO BURNS.

NASA-S-67-4346

LN_2

IN CASE OF ACCIDENT

IF THIS OCCURS 	DO THIS 
SPILL OR LEAK	KEEP UNNECESSARY PERSONNEL AWAY. APPROPRIATE PERSONNEL REQUIRED. APPROPRIATE SELF-CONTAINED BREATHING APPARATUS IN SPILL AREA. FOG IN FORM OF CONDENSED MOISTURE USUALLY INDICATES VAPOR AREA. SHUT OFF LEAK SOURCE(S) OF SUPPLY USING PROPER EQUIPMENT.
FIRE	NITROGEN CAN HELP PUT OUT FIRE. SPRAY TANK WITH WATER IF IT IS EXPOSED TO FIRE.
EXPOSURE	REMOVE VICTIMS(S) TO FRESH AIR. IF NOT BREATHING, APPLY ARTIFICIAL RESPIRATION AND OXYGEN. THAW FROSTED AREAS WITH WATER. GET MEDICAL ATTENTION PROMPTLY.

APPENDIX G

1. Suggested lesson plan guide accompanied by notations to the instructor(s)

2. Suggested session quiz and related answer sheet

3. Selected support materials, including opaque projection materials, "Liquid Hydrogen," "Liquid Hydrogen Handling Techniques," and transparencies

Suggested Lesson Outline

for

Session 7

LIQUID HYDROGEN AND RELATED ASPECTS

Estimated Time	Item(s)
	1.0 Review of the highlights of the preceding session
	1.1 Review the objectives of the preceding session.
0005	1.2 Review the significant safety measures discussed.
	2.0 Objectives for this session and general uses of liquid hydrogen
	2.1 Place the following LH_2 objectives on the "flip chart," on the chalkboard, or in the opaque projector prior to class and then, with the aid of a pointer, state each of the objectives which follows: a. To gain further awareness of the general properties and the characteristics of LH_2 b. To become familiar with LH_2 hazards and safety measures c. To become cognizant of proper transfer and storage procedures d. To understand the role of LH_2 at both the Kennedy Space Center and the Manned Spacecraft Center
0010	2.2 Point out several uses made of LH_2 at KSC and MSC locations where used. (Include its use at KSC for booster purposes and at MSC for testing at the thermochemical facilities and for the Block I tank for Apollo fuel cell use.)

Estimated Time	Item(s)
	3.0 General properties and characteristics of LH_2
	3.1 Use transparency S-67-574 as a guide for discussing the general appearance of LH_2.
	3.2 Show transparency S-67-572, pointing out the physical characteristics of this cryogen. Compare its density with air (1.02) and point out that it is 14-1/2 times lighter than air at 32° F. (One gallon weighs only 0.59 lb.)
	3.3 Point out to the class that LH_2 is noncorrosive, forms combustible mixtures with oxidizers, and, when allowed to evaporate, becomes highly combustible with air over a wide range of mixtures.
0020	3.4 Stress the aspects of solubility, stability, and compatibility. Concerning compatibility, the following should be emphasized. a. LH_2 reacts violently with strong oxidizers. b. LH_2 ignites easily with oxygen, fluorine, and trifluoride. c. At LH_2 temperatures, most mild steels and ferrous alloys lose their ductility and become brittle. d. Concentrations of LH_2 caused by severe temperature changes must be taken into account in designing equipment.
	4.0 Hazards
	4.1 Tell the class that from a health standpoint, LH_2 is not toxic in the usual sense, but serious "burns" can result.
	4.2 Relate that expanding gas quickly vaporizing from a liquid state can exclude oxygen and cause asphyxiation.
	4.3 Display transparency S-67-577 and discuss this first-aid notice.

Estimated Time	Item(s)

4.4 Show transparency S-67-578, pointing out that, since LH_2 is so flammable and since the liquid-to-gas ratio of 1:780 is so great, hydrogen is readily ignited. Follow up with transparency S-67-4354, which discusses fire and exposure.

4.5 Summarize what to do in case of an accident by reviewing the data shown in transparency S-67-4347.

4.6 Relate that the most effective way to control LH_2 fires is to shut off the supply. CO_2, water, and steam are good extinguishing agents.

4.7 Point out that when major spillage occurs, an area at least 400 feet in radius from the source should be vacated. (Remember that the outer limits of the flame usually cannot be seen.) If leaks occur in enclosed areas, eliminate potential sources of ignition and adequately ventilate the area before entering it. If H_2 gas is burning, the chances of an explosion are unlikely.

4.8 Explain by means of a "flip chart" or chalkboard that an explosive hazard exists when LH_2 is trapped and its temperature rises above -400° F. Where liquid hydrogen is being stored or handled, all sources of ignition should be prohibited by the following means:

a. Prohibiting smoking

b. Using explosion-proof electrical equipment

c. Grounding all equipment properly to remove static electricity (See appendix G.)

d. Providing adequate ventilation

e. Using detection devices for monitoring potentially hazardous concentrations of LH_2

f. Utilizing proper pressure relief valves and blow-out disks to avoid pressure rupture of equipment

g. Testing all lines periodically for pressure and leaks

Estimated Time	Item(s)
0040	4.9 Summarize briefly the prohibition of ignition sources.
	5.0 Safety measures
	5.1 Stress the fact that all operations involving the handling of LH_2 will be performed by two or more men.
	5.2 Show transparency S-67-155 on the safe handling of LH_2.
	5.3 Demonstrate for personnel protection an especially designed cryogenics handling suit, preferably placed on an upright mannequin. Include the following: a. Loose-fitting leather or asbestos gloves b. High-top leather shoes free of nails c. Cuffless pant legs worn outside over shoe tops d. Protection for the head and face by use of a shield or hood which can deflect splashes coming from any direction e. Flame-resistant clothing free from static electricity f. A regenerative-type (closed system) oxygen mask which should be used alone for respiratory protection and only in an emergency
0055	5.4 Have the fire department representative explain how a "special hazards vehicle" is used to combat a potential hydrogen fire at the Center. Display picture S-67-17861 (on the bulletin board or the opaque projector) of the "special hazards vehicle."
0105	C L A S S B R E A K

Estimated Time	Item(s)
	6.0 Transfer and storage
	6.1 Underscore the fact that storage, transfer, and test areas must be kept free of ignition sources and must be frequently inspected.
	6.2 Emphasize the purpose and procedure of purging storage tanks, transfer lines, and venting systems prior to inducing LH_2 into a system.
	6.3 Show transparency S-67-4969 to illustrate a typical transfer operation using a rigid transfer line.
	6.4 Show, by displaying transparency S-67-4349, how a flexible transfer tube is used in a typical transfer operation.
	6.5 Have adequate water readily available for emergency use.
	6.6 Have personnel showers properly located for immediate use in an emergency.
0110	6.7 Provide a protected area for personnel safety during combustion of LH_2 or spillage from tanks, pipelines, and so forth.
	7.0 Materials and equipment used with LH_2
	7.1 Show transparency S-67-576 pertaining to materials.
	7.2 Use transparency S-67-569 to show suitable metals.
	7.3 Show transparency S-67-573 to depict nonmetals found suitable for this service.
	7.4 Stress that the following must be of approved design and materials: containers, pipes and fittings, gaskets, valves, pumps and hose, and pressure gages.
0125	7.5 Relate that large storage containers must be vacuum-jacketed tanks insulated with noncombustible material such as santocel, perlite, or superinsulation mylar, coated with reflective aluminum, including spacer. (Proper rupture-disks or pressure relief valves will be located between inner and outer shells.)

Estimated Time	Item(s)

8.0 Main storage

8.1 Stress the following with buildings where LH_2 is stored, especially at this Center.

a. Buildings must be well ventilated and made of noncombustible materials.

b. Diking must be high enough to contain 10 percent of the capacity of storage vessels.

c. Electrical equipment will conform to appropriate parts of the National Electric Code.

d. At least two access roads to transfer and storage sites will be provided.

e. Adequate water will be provided for flushing, safety showers, and decontamination.

f. All sites must be properly drained.

g. Adequate ventilation must be provided.

h. Tanks, piping, and equipment must be kept clean and free of grease and oil.

0130

8.2 Remind the class that LH_2 must be stored in stationary or mobile tanks of approved materials and construction required by ASME, ASTM, or ICC specifications.

9.0 Shipping

9.1 Indicate that the Code of Federal Regulations and ICC regulations cover shipping in liquid containers and serve as guides for the user.

0135

9.2 Restate that shipping containers must be insulated and vacuum-jacketed with proper pressure relief valves and that rupture disks are required (and sometimes venting for shipping over long distances). Spark arresters enable hydrogen flame to be burned off.

10.0 Liquid hydrogen overview

0145

10.1 Show the slides on "Liquid Hydrogen" for a general session review.

Estimated Time	Item(s)
	11.0 Session assessment
	11.1 Administer the quiz.
0155	11.2 Discuss the quiz items.
	12.0 Résumé and distribution of handout materials
	12.1 Recapitulate the high points of the session and state that safety aspects should be examined further in Part 5, Subpart 7 of the MSC Safety Manual.
0200	12.2 Announce the topic for the next session.

Notations to the Instructor

1. Set up the overhead transparency projector and appropriate transparencies before class.
2. Set up the "flip chart" using a "magic marker" to prepare several different pages. Use different colors of ink for purposes of variation.
3. Use the 30- by 40-in. photo of the Center to show where LH_2 is used and, in addition, state the uses made of LH_2 at the locations concerned.
4. Place the objectives for this session on a "flip chart," or for purposes of variation, use the opaque projector, and so forth.
5. Make arrangements to have the fire department representative explain how the "special hazards vehicle" is used to combat a potential hydrogen fire at the Center.
6. Prepare the slides for showing before commencement of class.
7. Prepare the handout materials for display prior to class, but distribute the materials while the class is completing the quiz.
8. Consider the possibility of demonstrating the proper clothing to be worn when needed to handle cryogenic fires, by placing proper attire on a mannequin. (Allow two persons approximately 10 to 12 minutes to "suit up" the mannequin.)
9. Review the Manned Spacecraft Center Safety Manual, Part 5, Subpart 7 and related materials prior to class.

Suggested Session 7 Quiz

LIQUID HYDROGEN AND RELATED ASPECTS

A. Multiple Choice

___ 1. The principal danger from certain cryogenic spills or leaks is fire. The proper ventilation of storage areas and provisions for promoting evaporation will help reduce the danger of fire. There is no efficient means of decontamination other than rapid vaporization and dilution with air. The aforementioned description best refers to which of the following?

a. Krypton
b. Helium
c. Hydrogen
d. Nitrogen
e. Oxygen

___ 2. One cryogenic liquid is transparent and odorless and has a density of about one-fourteenth that of water. It is not corrosive or significantly reactive. Moreover, the temperature of this liquid, which is so low it can solidify <u>any</u> liquid gas except one, is which of the following?

a. Argon
b. Krypton
c. Helium
d. Hydrogen
e. Nitrogen
f. Oxygen

___ 3. If liquid hydrogen contacts the skin or splashes into the eyes, what should be immediately applied?

a. Loose bandages
b. Heavy bandages
c. Cold water
d. Warm compresses
e. An ointment used for burns

___ 4. The potential hazards in handling a certain liquid stem mainly from three important properties: (1) the liquid is extremely cold, (2) very small amounts of liquid are converted into large amounts of gas, and (3) the issuing gas is highly flammable. Which of the following is such a liquid?

a. NHe
b. LH_2
c. LHe
d. LN_2
e. LOX
f. LXe

Session 7 Quiz (cont'd)

B. True or False

___ 1. The cloudy vapor that appears when a liquefied atmospheric gas is exposed to the air is condensed moisture and not the gas itself. The issuing gas is invisible.

___ 2. Nonsparking tools should be used in liquid hydrogen areas. Containers of liquid hydrogen should be vented or protected by a safety device which permits the escape of vapor but excludes entry of air.

___ 3. Liquefied atmospheric gases should be handled in well ventilated areas to prevent excessive concentrations of gas.

___ 4. If it becomes necessary to dispose of liquid hydrogen, it should be disposed of outdoors in well ventilated areas away from sources of ignition.

___ 5. If a person becomes groggy or loses consciousness while working with liquid hydrogen, all sources of ignition should be kept away.

___ 6. Liquid hydrogen weighs 2 pounds per gallon.

___ 7. A volume of liquid helium is heavier than an equal-size volume of liquid hydrogen.

C. Completion

1. At liquid hydrogen __________ mild steels and most ferrous alloys lose ductility and become brittle.

2. The most effective means of controlling a hydrogen fire is by shutting off the __________.

3. Liquid hydrogen __________ is maintained with approved types of pressure gages as required.

4. In liquid hydrogen storage tanks, the vacuum space between the inner and outer shells is equipped with either a __________ disk or a pressure relief device.

5. All valves, pumps, switches, and so forth used to transfer liquid hydrogen must be properly identified and __________.

Session 7 Quiz Answers

A. Multiple Choice

1. c
2. d
3. c
4. b

B. True or False

1. True
2. True
3. True
4. True
5. True
6. False
7. True

C. Completion

1. Temperature
2. Supply
3. Equipment
4. Rupture or burst
5. Tagged

APPENDIX G

ADDITIONAL COMMENTS ON LIQUID HYDROGEN HANDLING TECHNIQUES

by

Pat B. McLaughlan

Thermochemical Branch, Manned Spacecraft Center

Confinement

Confinement of liquid hydrogen storage and test areas must be avoided because of the possibility of a detonation resulting from the ignition of the combustible hydrogen gas. During unconfined test of hydrogen air mixtures, no detonations occurred when the mixture was ignited by a spark. However, it is essential to note the significance of confinement. Tests have indicated that for four-walled enclosures (three vertical walls plus ground) reproducible detonations could be obtained by the ignition of hydrogen air mixtures. No detonations were observed with two-walled confinement (one wall plus ground). As a result of the experiments in partial confinement, it becomes apparent that barricades should not be used to surround storage tanks completely. Dikes may be used to contain the spilled liquid but should be only large enough to prevent the liquid from flowing to an undesirable location.

Ventilation

Laboratory usage of liquid hydrogen often has additional potential hazards over large-scale outdoor usage because of the confinement provided by the laboratory enclosure. The laboratory must be sufficiently ventilated to prevent hydrogen accumulation, and the ventilation must be arranged so that air is conducted past the apparatus containing hydrogen. Exhaust fans should be located in the highest part of the room. Recommended ventilation rates are from 20 to 30 air changes an hour during normal operation.

Gas Detection

A combustible gas detection system should be provided as a means for the detection of escaped hydrogen. The detection head must be placed where it will sample the combustible mixture in question. The detection head should be located at an elevated point, since hydrogen rises rapidly. A single location does not insure adequate sensing, since the combustible mixture may be exhausted without passing the detector. Locating the sampling device in the ventilation system is usually ineffective because of the large volume of air being handled. Although the gas detection system may be advantageous, it should not be relied upon completely because of the problems of locating the detection head where it will sample the combustible mixture.

Electrical

Electrical components for use in hydrogen areas should be of the explosion proof category suitable for hydrogen air mixtures. Normal laboratory operations using hydrogen are considered to be included in the Class I, Group B, Division 2, designation of the National Electrical Code. Other nonexplosion-proof equipment can be enclosed and purged with an external source of uncontaminated air or inert gas.

Purge Requirements

All hydrogen transfer lines must be purged with gaseous nitrogen or gaseous helium before and after each liquid hydrogen transfer. A vacuum purge of all liquid hydrogen storage dewars is required to remove gaseous contamination and water vapor if the dewar has not been maintained under a positive pressure of hydrogen or inert gas. A vacuum purge shall be accomplished by evacuation to a vacuum level of 1000 microns or more. The hydrogen dewar shall be backfilled with inert gas or hydrogen gas following the vacuum purge.

Electrical Ground

An electrical ground (with a resistance to ground of less than 10 ohms) must be provided for all liquid hydrogen storage dewars. During transfer operations, the supply and receiving dewars as well as the transfer apparatus must be grounded. All grounding systems should be periodically checked to insure a resistance to ground of less than 10 ohms.

Lightning Protection

Lightning protection must be provided for all hydrogen storage and transfer areas. Hydrogen transfer must not take place if lightning is present.

Vent Stack Design

Hydrogen vent gas must be properly disposed of to prevent the accumulation of combustible vapors. The basic requirements for venting criteria are the following.

1. The vent must be long enough to warm the hydrogen to a temperature above the boiling point of oxygen under the most severe flow conditions. This will prevent liquid air or oxygen from flowing back into the vent line.

2. The vent line should include a suitable check-valve system to prevent the backflow of air into the system.

3. The discharge height of the vent stack should be 10 to 30 feet above surrounding obstacles.

4. An inert gas supply should be permanently connected to the vent stack. This inert gas purge may be used to purge the vent stack prior to venting hydrogen and to extinguish vent stack fires. The liquid hydrogen transfer area should

provide a safe area for the venting of the hydrogen delivery trailer. If venting of the delivery trailer is a potential hazard, provisions must be made for connection of the hydrogen delivery trailer vent to the facility vent stack.

Transfer and Supply Dewars

Transfer of liquid hydrogen should be performed in a closed system to prevent contamination by air or oxygen which will solidify in the presence of liquid hydrogen. The evaporated fluid must be piped to a proper discharge vent. A positive pressure must be maintained in the hydrogen dewar to prevent the diffusion of air and water vapor through the dewar vent port. The storage dewar must contain a low-pressure relief valve to maintain the dewar at a desired positive pressure and to exclude contaminative gases from the dewar. Portable dewars used to supply experimental apparatus should be in the laboratory area only long enough to effect the liquid transfer and should be stored outside in a suitable controlled area at all other times.

APPENDIX G

LIQUID HYDROGEN[5]

Slide No.	Slide Title	Slide Statement
1	On Handling Hydrogen	Here is a general view of hydrogen storage and transportation equipment.
2	General View of Loading Dock at Hydrogen Plant	The requirements involved in handling liquid hydrogen will be considered.
3	A Liquid Hydrogen Cylinder, with Liquid Nitrogen and Argon Cylinders	Liquid hydrogen is a cryogenic or low-temperature fluid, much like the other liquefied gases made, but with unique characteristics of its own.
4	Properly Attired Workman Handling Liquid Container	This means that liquid hydrogen must be treated with the same respect as other cryogenic fluids. Protective clothing must be worn — goggles or face shield, loose-fitting leather or asbestos gloves, long sleeves, and cuffless trousers over high shoes. All possible steps must be taken to avoid contact with the cold liquid or cold piping which can cause dangerous "burns."
5	General View of Hydrogen Storage and Transport Equipment	The first step toward eliminating this hazard is to handle liquid hydrogen only in special containers, ranging from laboratory-size flasks to huge tank cars. This is the only practical means of storing and transporting liquid hydrogen safely without having it boil away.
6	Simplified Cutaway Schematic of LSH-150	Like containers for other cryogenic fluids, liquid hydrogen containers are essentially extra-large thermos bottles in which the cold liquid is surrounded by a vacuum, generally combined with other insulation. In certain ways, substantial differences exist between these containers and those used for liquid oxygen or liquid nitrogen.

[5]These slides and part of the script have been reproduced from a film strip initially prepared and produced by the Linde Division of Union Carbide, Inc.

Slide No.	Slide Title	Slide Statement
7	Simplified Cutaway Schematic of LSH-150 with Table Comparing Boiling Points of Hydrogen, Oxygen, Argon, Nitrogen and Helium	Liquid hydrogen is extremely cold. Its boiling point of -423.2° F is lower than that of any other cryogenic fluid except liquid helium. Therefore, even in the best containers, evaporation losses will be a problem.
8	Cross-Section of Container with Liquid Nitrogen Shield	Some types of liquid hydrogen containers, such as the one shown here, include a liquid nitrogen shield for added refrigeration. All have vacuum-insulated lines and valves, but no insulation is perfect.
9	Simplified Cutaway Schematic of LSH-150 Showing Heat Leak	A small amount of heat leaks in, keeping the liquid hydrogen constantly simmering around its boiling point. Therefore gaseous hydrogen is always present along with the liquid.
10	Volume Comparison of Liquid and Gaseous Hydrogen	As with any other cryogenic fluid, confined vaporization can be a hazard, since 1 cubic foot of liquid hydrogen will make 840 cubic feet of hydrogen gas at atmospheric pressure and temperature. Vaporization can build up destructive pressures if the expanding gas is not released.
11	Top of LSH-150 with Relief Valve Highlighted	Therefore, steps are taken to release gas if the pressure gets too high. For example, this liquid hydrogen cylinder has a pressure relief valve that opens whenever the gas pressure reaches 10 psi.
12	Top of LSH-150 with Container Bursting Disk Highlighted	Also, a bursting disk will take over if the valve fails to operate. The disk bursts at 48 psi.
13	Top of LSH-150 with Casing Bursting Disk Highlighted	The vacuum casing is also provided with a bursting disk to release pressure if an internal leak lets hydrogen seep into the insulation space. This disk breaks at 18 psi.
14	Closeup of LSH-150	It is normal for a liquid hydrogen container to vent gas to the air. The gas itself is invisible, but under some atmospheric conditions water vapor from the air can be seen condensing in the cold gas.

Slide No.	Slide Title	Slide Statement
15	LSH-150 and Gaseous Hydrogen Cylinder with Superimposed Type: PREVENT LEAKS?	The idea of letting hydrogen escape into the air contradicts one of the basic tenets of safety stressed in talking about gaseous hydrogen. Gas cannot be prevented from escaping from liquid hydrogen, so it becomes imperative to keep this constant leakage from creating a dangerous condition.
16	LSH-150: LIQUID HYDROGEN — Safety STRATEGY . . .	This can be done by preventing the accumulation of dangerous concentrations of hydrogen gas in the air wherever liquid hydrogen is handled.
17	Liquid Hydrogen Area with Fence in Foreground	Liquid hydrogen should be handled and stored outdoors as much as possible. Any area where hydrogen is used or stored should be located at some distance from other buildings, fenced to keep out unauthorized personnel, and posted to warn against smoking and other sources of ignition.
18	Simplified Schematic of Plant Ventilation	If hydrogen must be handled indoors, the building must be thoroughly ventilated from the highest point under the roof to prevent accumulation of explosive mixtures.
19	General View of Liquid Hydrogen Area with Truck Loading	Liquid hydrogen containers must be handled with proper care to minimize the possibility that dangerous concentrations of gas will accumulate in work areas.
20	Man Inspecting Valves of a Liquid Hydrogen Cylinder	Valves, piping, pressure relief valves, and bursting disks must be inspected and maintained so that a malfunction does not suddenly release a large quantity of hydrogen gas.
21	Truck with Brackets to Hold Liquid Hydrogen Cylinders	In transporting liquid hydrogen containers, they should be securely fastened in place so that jostling will not damage the container internally, thereby causing excessive amounts of hydrogen to flash off.
22	Man Preparing to Transfer Liquid Hydrogen	When liquid hydrogen is transferred from one container to another, a substantial quantity of hydrogen gas will inevitably be released into the air, so this operation must be performed outdoors. That is not the only concern in making a liquid transfer. Air also should be kept from getting into the liquid hydrogen or even into the neck tubes of the containers.

Slide No.	Slide Title	Slide Statement
23	Cutaway of LSH-150 with Freezing Points of Other Gases Compared to Boiling Point of Hydrogen	Liquid hydrogen is so cold that its boiling point is below the freezing points of the gases in the air.
24	Particles of Air Freezing in Liquid Hydrogen	Thus, if air comes into contact with liquid hydrogen, some air will condense into the liquid and freeze solid. These particles can close valves and passages, causing a dangerous pressure buildup in the container. Moreover, the frozen oxygen from the air can react explosively with liquid hydrogen if ignited.
25	Liquid Nitrogen Cylinder Being Put in Place	To prevent these hazards from developing, a special transfer procedure must be followed. Here, a container of liquid nitrogen is being made ready for its part in the transfer operation. The liquid nitrogen may be used for preliminary purging and for the nitrogen shield if the container has one.
26	Man Grounding Containers	First, all containers and piping must be electrically grounded to make sure a spark caused by static electricity does not ignite the hydrogen. This is done by means of ground wires connected to a grounding rod driven into the earth.
27	Purging with Liquid Nitrogen	Purging the empty container with liquid nitrogen drives out air and also precools the container to minimize the flash-off of hydrogen. When the container has been cooled to the temperature of liquid nitrogen, the liquid nitrogen is removed.
28	Instruction Booklets	One important point to remember during purging, filling, or any operation is that most hydrogen containers are lightly built to minimize heat leak. This means that there are definite limits of weight, pressure, and movement which must not be exceeded. The special instructions for each type of container must be carefully followed.

Slide No.	Slide Title	Slide Statement
29	Purging Container with Helium	Before it is filled with hydrogen, the container and all valves and passages must be purged with helium, since this is the only gas that won't freeze in liquid hydrogen. Hydrogen gas may may also be used, but it must be gas obtained as flash-off from liquid. Never use ordinary cylinder hydrogen. It normally contains freezable impurities.
30	Transfer Line Being Connected to Liquid Hydrogen Cylinder	After the vacuum-insulated transfer line is also purged with helium to drive out the air it contains, the bayonet connection is attached to the liquid container from which hydrogen will be drawn.
31	Purging Transfer Line with Hydrogen	The liquid withdrawal valve is cracked momentarily to flush any air from the valve and transfer line. It is closed immediately to prevent moisture from collecting on the dip tube. The operator points the transfer line safely away from himself.
32	Hydrogen Transfer Taking Place	The tube is inserted into the empty container as the liquid valve is opened again. The insulated part of the line should remain free of frost during the transfer. If frost forms on it, this indicates a defective line, and the transfer should be stopped immediately.
33	Instruction Booklets	One important caution is that liquid hydrogen containers should not be overfilled. A small increase in the heat content of the liquid will cause a great expansion of volume. Here again, the special instructions for each type of container must be followed.
34	Transfer Line Being Removed	When the transfer is completed, the withdrawal valve is closed and the transfer line is withdrawn very rapidly to prevent condensed air from entering the neck tube.
35	Relief Valve on LSH-150	Keeping air out of liquid hydrogen is just as important after the transfer has been completed. It will be recalled that the pressure relief valve prevents destructive pressures from building up inside the container and that it operates in one direction only. It lets gaseous hydrogen out, but it will not let air in.

Slide No.	Slide Title	Slide Statement
36	25-Liter Container with Check Valve	Something must serve the same purpose for smaller containers that don't have safety valves. The answer is to place a suitable check valve over the neck tube opening. Even the smallest dewar containing liquid hydrogen must be kept covered to prevent air from entering.
37	Liquid Hydrogen — Safety Strategy	To sum up the safety strategy for handling liquid hydrogen, the following are two main rules: (1) prevent gas accumulation in the air as a result of the venting of hydrogen containers, and (2) keep air from contact with liquid hydrogen by following correct procedure in transfer operations.
38	Gaseous Hydrogen — Safety Strategy	Since gaseous hydrogen is always present along with the liquid, we must follow the safety strategy prescribed for handling gaseous hydrogen: prevent leaks in gas storage and piping systems, prevent fire, and be ready for emergencies. Another set of rules that applies to handling liquid hydrogen. . .
39	Liquefied Gases — Safety Strategy	. . . is the safety strategy for handling all liquefied gases: avoid personal contact with cold products or piping to prevent "burns," maintain equipment to minimize the risk of accident, and follow correct procedures at all times.
40	Liquid Cylinder Truck Leaving Hydrogen Plant	If these rules are followed faithfully by everyone who works with liquid hydrogen, this product should be handled in perfect safety. Everyone must do his part to maintain an enviable safety record. Respect for LH_2, rather than fear of it, is essential for handling this cryogene safely.

TABLE II.- LOCATIONS AND TYPES OF CRYOGENIC LIQUIDS

USED AT THE MANNED SPACECRAFT CENTER

Building	LOX	LH_2	LN_2	LHe	LA
[a]7	X		X		
13			X		
15			X		
32	X		X	X	X
[b]33			X	X	
222	X		X		
262			X		
350	X				X
351	X		X	X	
353			X		
354	X	X		X	
356			X		
Off Site[c]	X		X		

[a]Various gaseous and liquid mixtures are used on a regular basis for calibration purposes.

[b]Building 33 also uses liquid dioxide.

[c]This source location is a service facility located off of the Site.

NASA-S-67-574

LH_2 CHARACTERISTICS

- TRANSPARENT
- COLORLESS
- ODORLESS
- DENSITY IS ABOUT 1/14TH THAT OF WATER
- NOT CORROSIVE NOR SIGNIFICANTLY REACTIVE
- CAN SOLIDIFY ANY GAS EXCEPT HELIUM
- HAS RELATIVELY HIGH COEFFICIENT OF THERMAL EXPANSION

NASA-S-67-572

LH_2 CHARACTERISTICS

- BOILING POINT .... -423° F
- DENSITY (LB / GAL) 0.59
- AUTO IGNITION TEMPERATURE .... 1075° F
- FLAMMABILITY LIMITS IN AIR BY VOLUME (H_2 GAS) .... 4.0 TO 74.2 PERCENT
- VISCOSITY (MICROPOISES) 140
- CRITICAL TEMPERATURE .... -400° F
- CRITICAL PRESSURE (PSIA) .... 188°

NASA-S-67-577

LH_2 FIRST AID NOTICE

IF A PERSON BECOMES GROGGY OR LOSES CONSCIOUSNESS WHILE WORKING WITH LH_2, GET HIM TO A WELL VENTILATED AREA. IF BREATHING HAS STOPPED, APPLY ARTIFICIAL RESPIRATION. WHENEVER A PERSON LOSES CONSCIOUSNESS, SUMMON A PHYSICIAN IMMEDIATELY. KEEP ALL SOURCES OF IGNITION AWAY FROM THE OVERCOME PERSON.

NASA-S-67-4354

LH_2

(—423°F OR 20°K)
(COLD AND ODORLESS)

MAJOR HAZARDS

- FIRE

  LH_2 IS EXTREMELY FLAMMABLE. HYDROGEN-AIR MIXTURES ARE READILY IGNITED AND MAY BE EXPLOSIVE IN CONFINED SPACES. FLAMES ARE USUALLY INVISIBLE. HYDROGEN FROM 3% TO 96% MIXTURE IN AIR IS EXPLOSIVE.

- EXPOSURE

  COLD GAS OR LIQUID MAY CAUSE SKIN OR EYE INJURIES SIMILAR TO BURNS. THOUGH VAPOR IS NOT TOXIC, BREATHING IT MAY CAUSE SUDDEN UNCONSCIOUSNESS BECAUSE OF LACK OF OXYGEN.

NASA-S-67-578

POTENTIAL HAZARDS IN HANDLING LH_2 STEM
CHIEFLY FROM THREE IMPORTANT CHARACTERISTICS

- LH_2 IS EXTREMELY COLD
- VERY SMALL AMOUNTS OF LIQUID ARE CONVERTED INTO LARGE AMOUNTS OF GAS
- THE ISSUING GAS IS HIGHLY FLAMMABLE

NASA-S-67-4347

LH_2

IN CASE OF ACCIDENT

IF THIS OCCURS	DO THIS
SPILL OR LEAK	SHUT OFF SOURCE(S) OF IGNITION. NO SMOKING OR USE OF FLARES PERMITTED. KEEP UNNECESSARY PERSONNEL AWAY FROM AREA. SELF-CONTAINED BREATHING APPARATUS AND GLOVES ARE REQUIRED TO ENTER SPILL AREA. SHUT OFF SOURCE(S) OF SUPPLY BY USING PROPER EQUIPMENT. FOG IN FORM OF CONDENSED MOISTURE USUALLY INDICATES WATER VAPOR.
FIRE	PERMIT ESCAPING HYDROGEN TO BURN IF FLOW CANNOT SAFELY BE SHUT OFF. SPRAY TANK WITH WATER IF IT IS EXPOSED TO FIRE. IF SUBSTANTIAL PART OF INSULATION JACKET AND INSULATION ARE GONE, VACATE GENERAL AREA.
EXPOSURE	REMOVE VICTIM(S) TO FRESH AIR. IF NOT BREATHING, APPLY ARTIFICIAL RESPIRATION AND OXYGEN. THAW FROSTED AREAS WITH WATER. GET MEDICAL ATTENTION PROMPTLY.

NASA-S-67-155

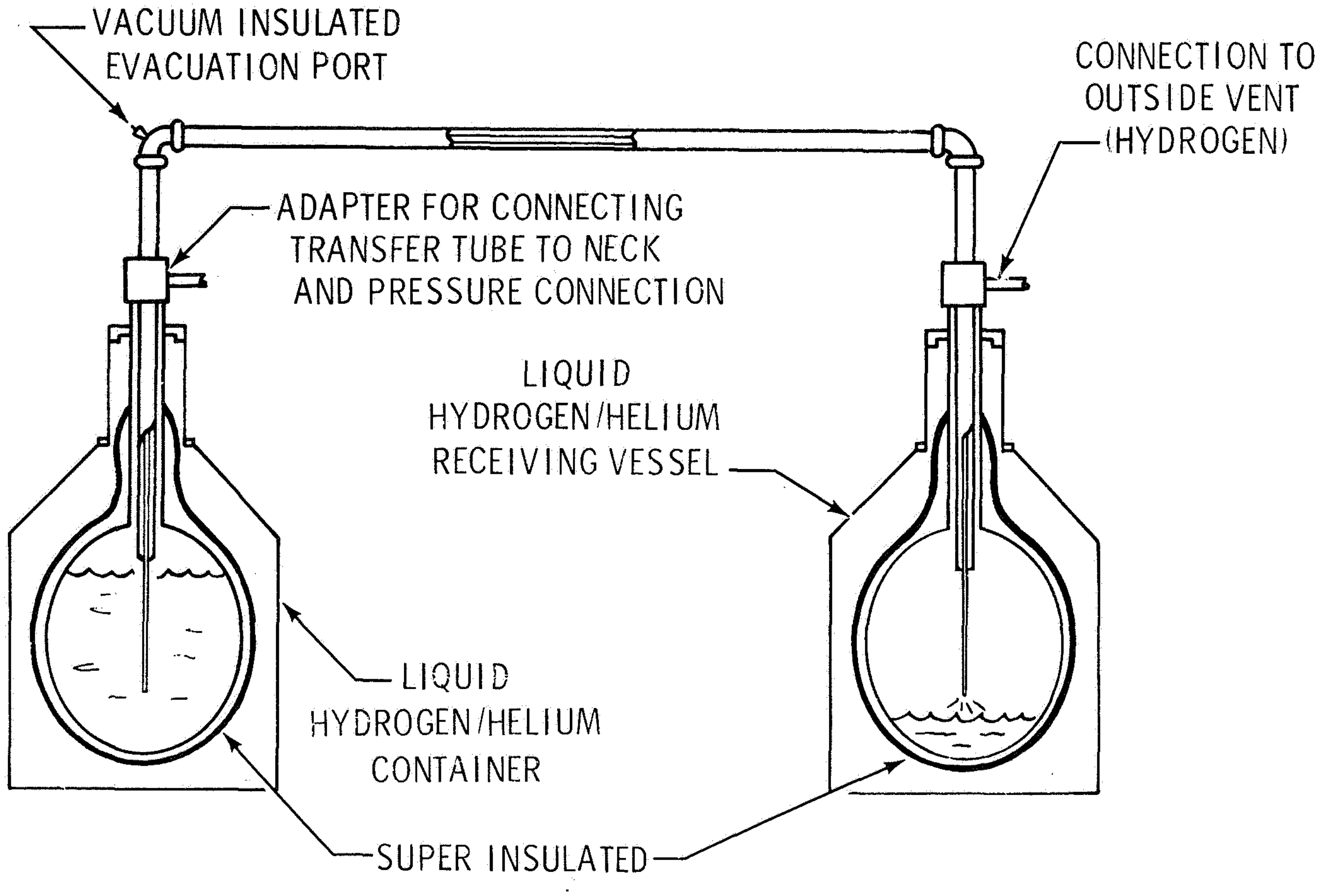
HYDROGEN - SAFETY AND HANDLING

- AVOID CONTACT
- USE PROPER STORAGE AND HANDLING EQUIPMENT
- PROVIDE ADEQUATE VENTILATION
- PREVENT SOURCES OF IGNITION
- OBTAIN A THOROUGH KNOWLEDGE OF THIS ELEMENT BEFORE WORKING WITH IT

NASA-S-67-4969

TYPICAL TRANSFER OPERATION

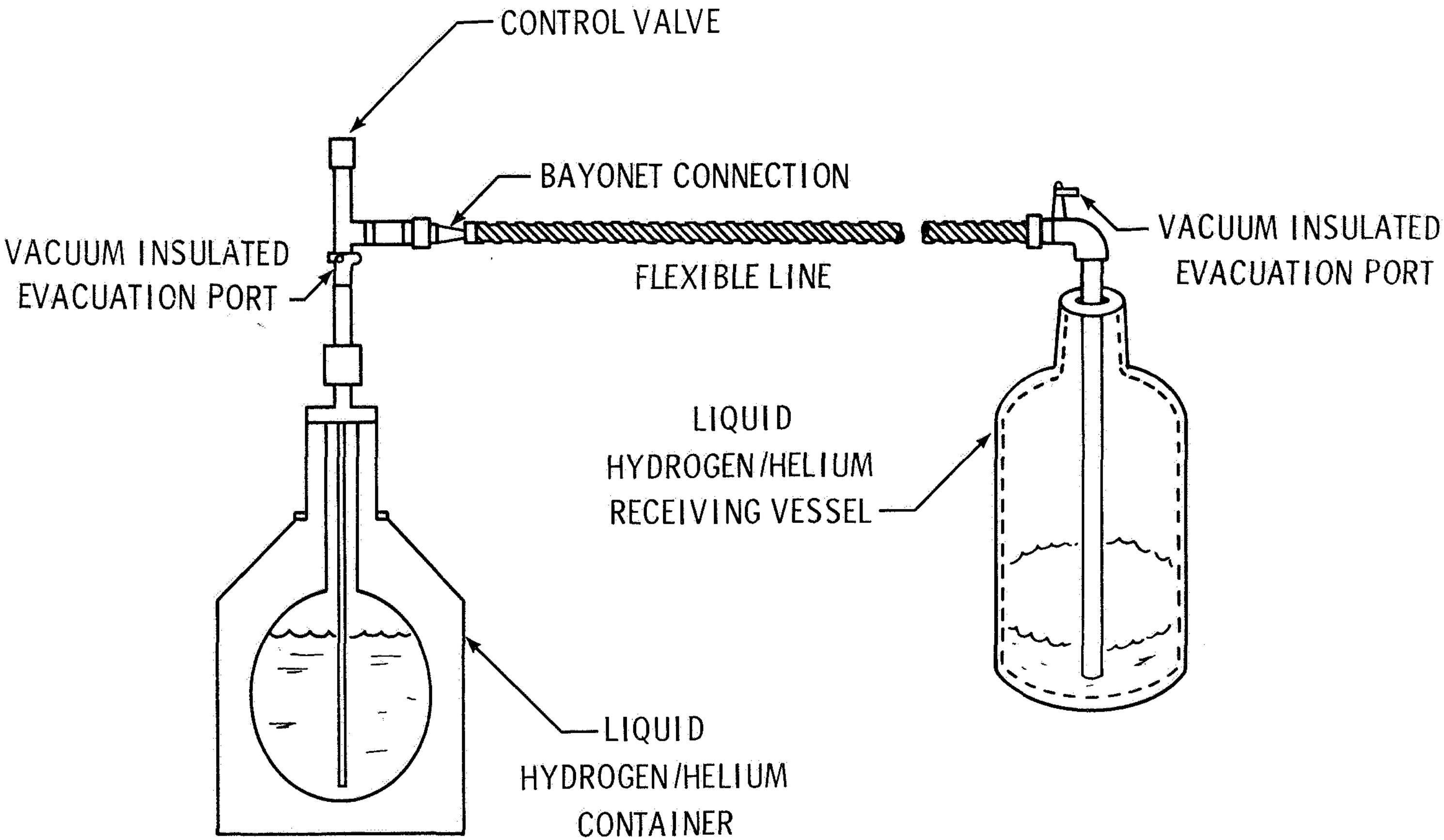
(RIGID TRANSFER TUBE)



NASA-S-67-4349

TYPICAL TRANSFER OPERATION

(FLEXIBLE TRANSFER TUBE)



NASA-S-67-576

MATERIALS UTILIZED WITH LH_2

THE ABILITY OF MATERIALS TO RETAIN SATISFACTORY PHYSICAL PROPERTIES WHILE WITHSTANDING THERMAL STRESSES CAUSED BY LARGE TEMPERATURE CHANGES IS EXCEEDINGLY IMPORTANT.

NASA-S-67-569

METALS SUITABLE FOR USE WITH LH_2

- ALUMINUM
- BRASS
- BRONZE
- COPPER
- EVERDUR
- MONEL
- STAINLESS STEEL

SA-S-67-573

NONMETALS SUITABLE FOR USE WITH LH_2

- DACRON
- TEFLON
- KEL-F
- ASBESTOS IMPREGNATED WITH TEFLON
- MYLAR FILMS
- NYLON

APPENDIX H

1. Suggested lesson plan guide accompanied by notations to the instructor(s)

2. Suggested session quiz and related answer sheet

3. Selected support materials including "Liquid Helium" and transparencies

Lesson Plan

for

Session 8

LIQUID HELIUM AND RELATED ASPECTS

Estimated Time	Item(s)
	1.0 Review of the preceding session
0005	1.1 Touch upon the "high points," using the objectives of preceding session as a guide. Obtain comments or questions from the class on the aforementioned session before commencing coverage of this session.
	2.0 Major objectives for LHe
0010	2.1 State, by means of "flip chart" (or chalkboard), the primary objectives for LHe session. These objectives are as follows:

a. To familiarize the course participants with the unusual properties of liquid helium in comparison with other cryogenic liquids

b. To acquaint the class members with safety precautions pertaining to LHe

c. To become cognizant of the utilization and potential of helium at this Center

3.0 Overview of LHe

3.1 Relate that recent advances in space (cryopumping in simulators), missile, and electronics fields, along with demands for research applications, have increased the importance of LHe among cryogenic liquids.

3.2 Point out that while helium gas is found in air in the ratio of 5 parts per 1,000,000, commercial helium is usually obtained from natural gas where it usually exists in concentrations of 0.5 to 2.5 percent by volume.

Estimated Time	Item(s)
	3.3 Use transparency S-67-151 to show the boiling point of LHe. Explain the significance of the "Lambda Transition;" then further reinforce learning by having the following available for viewing.
	"As a liquid, helium exhibits two highly different characters depending on temperature. Between the boiling point (4.2° K) and the lambda point (2.18° K), it is known as LHe I and exhibits characteristics typical of other liquids. At 2.18° K, the liquid undergoes a transition, called the "lambda transition," and becomes LHe II. This colder liquid exhibits the phenomenon of superfluidity (virtually zero viscosity) and attains an extremely high thermal conductivity — more than 1000 times greater than that of copper."
0020	3.4 Recommend to the class members that the growth and development of helium as a cryogenic liquid is being covered in various articles such as the one authored by Dr. Leo Garvin entitled "Helium — Today and Tomorrow." (Hold the article reprint in hand so that the class members may see exactly what is being discussed.)
	4.0 Physical properties and the uniqueness of some of LHe's properties
	4.1 By means of a "flip chart," point out the following facts.
	a. At sea level, LHe has a boiling point of -452.1° F, a mere 7.6° F above absolute zero.
	b. LHe is the only known substance which remains liquid under ordinary pressures at temperatures close to absolute zero.
	c. LHe is colorless.
	d. LHe is nontoxic.
	e. LHe has a density approximately one-eighth that of water.
	f. LHe is inert (under all temperature and pressure conditions).

Estimated Time	Item(s)
	4.2 Stress the unique physical properties of LHe, including its movement, zero entropy, superfluidity, superconductivity, and so forth.
	4.3 Use transparency S-67-91 to define superconductivity mentioned in preceding item 4.2 and point out that with a very low power source, power can be started in a superconductor. Also, when the power source is removed, the current continues to flow indefinitely. Add, too, that the current creates a magnetic field around the superconductor. This magnetic field also remains constant indefinitely.
	4.4 Display transparencies S-67-89 and S-67-95 to show the class some of the more common elements and compounds among the 25 elements and the 250 metal alloys and compounds known to exhibit superconductivity between 18° and 0° K.
	4.5 Indicate that superconductive windings in electromagnets would result in substantial reductions in power requirements, elimination of heating, and reduction in size.
	4.6 Point out that the ability to "turn off" and "turn on" resistivity in a superconductor by applying and removing a magnetic field has led to switching devices called <u>cryotons</u>.
0030	4.7 After briefly summarizing both the common and unique physical properties of LHe (including its movement, superconductivity, zero entropy, superfluidity, and so forth), point out that many LHe properties will be discussed in some detail on the slide presentation which follows.
	<u>5.0 Aspects of LHe emphasizing safety</u>
	5.1 Present "Liquid Helium" slides and remind the class participants to be mindful of the following: a. Characteristics of LHe and where located in the United States b. LHe delivery system — equipment and safety precautions c. Containers and equipment; safety and handling LHe

Estimated Time	Items(s)
	d. Transfer system
	e. LHe applications
0055	5.2 Hold a question and answer discussion on the slide presentation.
0105	C L A S S B R E A K
	6.0 Safety precautions
	6.1 Present the following transparencies on LHe safety in the following order. a. S-67-460 b. S-67-461 c. S-67-450 d. S-67-459 e. S-67-451 (optional) f. S-67-455 (optional)
0110	6.2 Point out that the safety standards for LHe will be added to the MSC Safety Manual (MSCM 1700).
	7.0 LHe specification(s) and utilization
	7.1 State that the Bureau of Mines and the Air Reduction Co., Inc., serve as LHe distributors in accordance with CGA regulations. Display transparency S-67-154 and discuss the specifications for liquid helium.
	7.2 Use transparency S-67-456 to show some of the applications of LHe.
	7.3 Discuss uses of LHe at the Center and the locations where used. (Include the research and calibration going on in building 32 and 351.)
	7.4 Discuss the special handling procedures used at this Center.
0120	7.5 Show the silent film on LHe. Narrate the film describing the use of a liquid level finder in the study of helium oscillations.

Estimated Time	Item(s)
	8.0 Cryogenic system design
0140	8.1 Utilize class time to work on system design while the instructor(s) are available to render assistance.
	9.0 Session assessment
	9.1 Administer the quiz.
0150	9.2 Discuss the quiz items.
0155	10.0 Summary and distribution of handout materials
	10.1 Recapitulate the major points covered in the session, making certain that all objectives were met.
	10.2 Announce the topic for the next session.
0200	10.3 Distribute the handout materials to the class participants.

Notations to the Instructors

1. The subject of liquid helium should be a fascinating one to teach because of the uniqueness of this liquid and some equally fascinating audiovisual support material to supplement instruction.

2. Preview and set up appropriate audiovisual equipment and materials prior to class: motion picture projector and film, slide projector and slides arranged in proper presentation sequence, and the overhead transparency projector and transparencies.

3. Review the script which has been prepared for the slide presentation.

4. Use the "flip chart" and/or the chalkboard as appropriate to present the session objectives and, later, various properties of LHe.

5. When the class participants work on the system design, mix with the participants both to render assistance and help motivate the class members.

6. Have specific handout items ready to be distributed at the end of this session.

7. When temperatures are discussed, vary the temperature scales so as to permit the participants an opportunity to think in terms of the four different temperature scales.

8. Refer to the article entitled "Helium — Today and Tomorrow, II. Liquid Helium" to point out the performance of signal-to-noise ratio for deep space probes.

Session 8 Quiz

LIQUID HELIUM AND RELATED ASPECTS

A. True or False

___ 1. As a result of recent advances in the electronics, missile, and space fields, liquefied helium is fast becoming one of the most important cryogenic liquids.

___ 2. Unlike the more common cryogenic fluids, the properties of liquefied helium are unusual and, as a result, special equipment and special handling equipment are required.

___ 3. Helium is usually obtained commercially by separation from selected or special natural gas.

___ 4. Liquid helium is produced by liquefication of very pure helium gas using various ultra-low temperature refrigeration techniques.

___ 5. Liquid helium is shipped in small containers (25 to 500 liters in size) which are placed in either a horizontal or an inverted position.

___ 6. Liquid helium has the ability of "creeping up over" the walls of its container when the temperature is lowered to 2.19° Kelvin.

___ 7. Dense helium gas can be used as a refrigerant in a cryo-pumping device to produce a "near perfect vacuum" for space simulation chambers.

___ 8. The small size of its molecules and the fact that it is normally absent from the atmosphere in detectable quantities make gaseous helium an ideal tracer for use in leak detection.

___ 9. The coldest substance man has produced thus far is liquid helium.

___ 10. Liquid helium is heavier by weight than liquid hydrogen.

B. Multiple Choice

___ 1. Helium exists in natural gas concentrations of ______ to ______ by volume.

a. 0.5 to 2.5 percent
b. 2.6 to 5.0 percent
c. 5.1 to 7.5 percent
d. 7.6 to 10 percent
e. 10.1 to 12 percent

Session 8 Quiz (cont'd)

___ 2. At approximately -452° Fahrenheit, all of the cryogenic fluids except one will solidify. Which one will not solidify?

a. Argon
b. Helium
c. Hydrogen
d. Oxygen
e. Nitrogen

___ 3. Which of the following safety precautions is not applicable to liquid helium?

a. Helium should not be exposed to air.
b. Helium must be kept away from ventilated areas.
c. Contact should be avoided with other liquids.
d. Contact should be avoided with cold gases.
e. Contact should be avoided with cold surfaces.

___ 4. When purging cryogenic liquid vessels prior to use, it is essential that all but one of the following be done or considered:

a. Matter considered undesirable to product purity should be removed.
b. Matter which could be injurious to equipment functioning should be removed.
c. Matter considered hazardous to personnel should be removed.
d. Knowledge of the freezing and boiling points of all likely contaminants should be known.
e. Knowledge of barometer and temperature readings outside the purging area should be known.

___ 5. Virtually all of the world supply of commercial helium gas has been found in national wells located in which group of states?

a. Georgia, Florida, Alabama, Louisiana, and Mississippi
b. Washington, Oregon, California, Nevada, and Indiana
c. Kansas, Texas, Oklahoma, Arizona, and New Mexico
d. Tennessee, Kentucky, Illinois, Indiana, and Ohio
e. New York, Vermont, New Hampshire, Massachusetts, and Connecticut

___ 6. Which cryogenic liquid has the most potential of increasing electrical conductivity?

a. Liquid argon
b. Liquid helium
c. Liquid hydrogen
d. Liquid oxygen
e. Liquid nitrogen

Session 8 Quiz Answers

A. True or False

1. True
2. True
3. True
4. True
5. False
6. True
7. True
8. True
9. False
10. True

B. Multiple Choice

1. a
2. b
3. b
4. e
5. c
6. b

LIQUID HELIUM[6]

Slide No.	Slide Title	Slide Statement
1	Space Environment Chamber	One of the fastest developing major technologies is cryogenics, the technology of the "super cold" which is being used on a daily basis at the Manned Spacecraft Center in places such as the Environmental and Space Simulator shown here.
2	One of the Several Manufacturers of LHe	Liquid helium, the coldest liquid that man can produce, is vital to the growth of cryogenics, and the quantities required increase daily. Industry is taking the necessary steps to meet the needs of the nation, as well as of the world.
3	Liquid Helium Temperature Chart	Liquid helium has a boiling temperature of -452° F, only 7.6° over aboslute zero. It remains liquid down to absolute zero.
4	Cryogenic Liquids Comparison Chart	It is far colder than any other cryogenic liquid. Notice that LHe is colder than LH_2, LNe, LN_2, and LOX.
5	Helium Map	Commercial helium is found mixed with natural gas in amounts generally ranging from 0.3 percent to usually no more than 2 percent. Almost all of the world supply is found in natural gas wells located in the Southwestern United States shown here on the map.
6	U.S. Producers Map	Until recently, gaseous helium has been produced by the U.S. Bureau of Mines and one private producer, Kerr-McGee. Helium production facilities are in the locations shown.
7	Photograph of Otis Plant	This large liquid helium plant, located in Otis, Kansas, produces 800 liters an hour, equivalent to 15 000 000 cubic feet of gas per month. This plant is presently the largest single source of liquid helium in the world.
8	Chart showing Helium Liquid and Gas Delivery System	The plant pictured in the preceding slide and shown here on the upper left side manufactures helium in liquid form to facilitate over-the-road shipment in a unique fleet of tractor trailers, each of which has a capacity of 10 000 gallons of liquid helium,

[6]These slides and parts of the script have been reproduced from a filmstrip prepared and produced by the Linde Division of Union Carbide, Inc.

Slide No.	Slide Title	Slide Statement
		equivalent to 1 000 000 cubic feet of gas. Liquid helium is delivered in dewars, and tube trailers are used for both large volume storage and delivery.
9	Loading of a Tractor	Here are two custom-designed tractor-trailers which represent the most efficient cryogenic vessels of their size ever built for over-the-road service. Before this, long distance shipment of volume quantities of helium had been by gaseous rail car. These tractor-trailers, each of which has the capacity of three rail cars, represent a major advance over rail shipment. Unlike the rail cars, these can reduce round trip time considerably.
10	Valves at Rear of Truck	The valve equipment shown here at the back of the tractor-trailer is simple. With this valving arrangement, liquid helium can be unloaded into dewars directly; it can be fed into the plant for conversion to gas; or gaseous helium can be drawn from the truck to fill cylinders or gaseous tube trailers.
11	Liquid Station Schematic	Here is a schematic of the liquid and gas delivery system in which the trailer becomes an integral part of the distribution plant. Liquid dewars are filled directly from the trailer, whereas liquid is vaporized and compressed before filling gaseous cylinders and gaseous tube trailers. This closed system is such that even the gas which flashes from the liquid dewar filling operation is recovered. Monitoring equipment at each plant maintains high purity of gaseous helium. A hydrocarbon detector automatically shuts down the compressor if the hydrocarbon level rises to 2 to 4 parts per 1 000 000 . A trace oxygen analyzer shuts down the compressor if oxygen exceeds 10 parts per 1 000 000. In addition, filled tube trailers and cylinders are tested for moisture and oxygen. All locations have gas chromatographs for use where certified purity is required.
12	Loading of Cryogenic Service Truck	As a final link in the distribution chain, cryogenic service trucks deliver liquid helium directly to customers from receiving points to guarantee a steady supply and meet customers' emergency requirements.
13	Liquid Helium Must be Handled Carefully	In transporting liquid helium, proper transfer and handling care must be exercised for several reasons.
14	Cartoon — "Sensitive to Heat"	Liquid helium is extremely sensitive to heat and must be protected from it or the liquid will boil off and be lost.

Slide No.	Slide Title	Slide Statement
15	Cartoon — "Liquid Expensive, Dewars Fragile"	Liquid helium is valuable and the dewars are expensive and fragile.
16	Cartoon — "Standard Handling Precautions"	Although the liquid is inert, handlers must observe the usual precautions taken with any cryogenic fluid, that is — gloves, face shields, and so forth.
17	Liquid Nitrogen Shielded Dewar Schematic	Liquid helium is conveniently handled and stored in two basic types of containers — the liquid-nitrogen-shielded dewar and the gas-shielded dewar. This is a liquid-nitrogen-shielded dewar. It is triple heat shielded by an outer vacuum space, a liquid nitrogen shield, and an inner vacuum space next to the tank of liquid helium itself. The entire unit is suspended within a stainless steel outer casing.
18	Gas Shielded Dewar Schematic	This is a gas-shielded dewar. As the liquid helium slowly vaporizes, the gas is vented through a shield surrounding the liquid tank. The cold gas passing through this shield in the vacuum jacket to the outside absorbs incoming heat and serves as an effective heat barrier. Generally, the nitrogen-shielded dewars are the smaller capacities and the gas-shielded, 100-liter dewars shown here are larger.
19	C. G. Top View	All containers have safety devices, liquid withdrawal connections, and pressure gages. Here you can get a close look at these on one type of gas-shielded dewar.
20	H. G. Top View	Here is another type of gas-shielded dewar, with a somewhat different arrangement of safety devices, liquid withdrawal connections, and pressure gages.
21	H. N. Top View	A typical liquid-nitrogen-shielded dewar has this arrangement.
22	Neck Details, Nitrogen-Shielded Dewar	This liquid-nitrogen-shielded container is safer because it has dual relief passages. Helium vapor normally vents through the fill line. If this fill line should become plugged with frozen moisture or frozen air, the resulting pressure buildup may vent through a secondary passage. Vents are shown by asterisk.
23	Neck Details, Gas-Shielded Dewar	This gas-shielded container has three relief passages. The normal vent is through the gas shield. When venting exceeds the capacity of this line, an intermediate

Slide No.	Slide Title	Slide Statement
		relief opens. The third passage provides additional relief. Vents are shown by asterisk.
24	Adapter	To withdraw liquid helium from nitrogen-shielded dewars, a special adapter is used. The function of the adapter is to permit pressurization of the dewar, forcing liquid helium out through the transfer tube into into the receiving vessel. Only helium gas is used as a pressurizing medium. Gas-shielded dewars have a separate connection for pressurization.
25	Transfer Tubes	Transfer tubes are available for transferring liquid from one container to another. These tubes are vacuum-jacketed to reduce heat leak.
26	Freeze-up Plug Locations	In handling liquid helium, care must be taken to avoid plugging the fill line and neck or vent line. The liquid will condense and freeze air and/or water vapor, forming plugs which prevent venting and consequently cause a pressure rise because of heat leak. Typical locations of such plugs are indicated. All connections leading to the liquid helium reservoir must be isolated from ambient air at all times. The connections are to be opened for liquid level measurement or insertion of of transfer tube. Prevention of plugs is most important. For removing plugs, the use of a special tool is suggested which will be discussed later.
27	Photo of Measurement of Liquid Level	Liquid level is determined by measuring the distance from the bottom of the dewar to the top of the liquid. This is done by means of a measuring probe. Several types of probes are available. Based on level measurement, the quantity of liquid is found by referring to a contents chart provided with the dewar.
28	Photo of Various Sizes of Dewars	These are typical liquid helium dewars. Containers range from 25 to 500 liters. Larger dewars are available on special request.
29	Important Points to Remember	There are three important "don'ts" in handling liquid helium containers.
30	Cartoon — "Don't Roll Dewars"	Don't roll dewars on a tilted axis since the inner container is supported by the neck only and will tend to snap off unless the dewar is kept in a vertical position.
31	Cartoon — "Don't Drop Dewars"	Don't drop dewars. Since they are supported by the neck, they are very fragile.

Slide No.	Slide Title	Slide Statement
32	Cartoon — "Avoid Mechanical Shocks"	Don't allow sudden mechanical shocks.
33	Applications — Liquid Helium	There are many applications for helium, both liquid and gas. Applications for liquid helium, many of which are now in the developmental stages, are increasing rapidly. New uses are being found in the electronics and heavy electrical fields, in the chemical and metallurgical industries, in aerospace fields, and in atomic energy applications.
34	Liquid Helium Increases	Because of its extreme cold, -452° F, liquid helium has characteristics which make it useful in research and industry. One, for example, is that liquid helium greatly increases electrical conductivity, or superconductivity, permitting huge reductions in the size of equipment used and permitting increased electrical capacity.
35	Liquid Helium Reduces Thermal Noise	Another characteristic of liquid helium is that it reduces thermal noise by minimizing electron movement. With little or no background noise in the circuit, sensitivity in such instruments as amplifiers and detectors is greatly increased.
36	Production Schematic	Helium is expensive to produce in liquid form. To extract commercial quantities requires a large plant investment and substantial energies at temperatures 100° lower than those commonly encountered in air separation plants.
37	Typical Application	However, in the new technologies of today a substantial demand exists for commercial quantities of liquid helium as well as gaseous helium. This demand will increase as these technologies mature.

NASA-S-67-4614

HELIUM SPECIFICATION

1. SCOPE

1.1 THIS DOCUMENT DESCRIBES THE SPECIFICATION REQUIREMENTS FOR GASEOUS AND LIQUEFIED HELIUM.

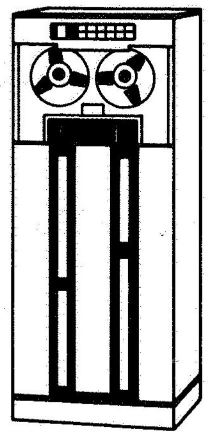
2. CLASSIFICATION

2.1 TYPES AND GRADES - TABLE 2.1 PRESENTS THE COMPONENT MAXIMA IN PPM' (V/V) UNLESS SHOWN OTHERWISE FOR THE TYPES AND GRADES OF HELIUM

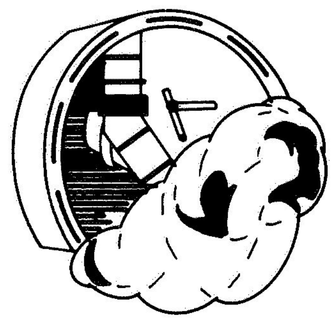
LIMITING CHARACTERISTICS	TYPE I (GASEOUS) GRADES										TYPE II (LIQUEFIED)	
	A	B	C	D	E	F	G	H	J	K	A	B
MIN. %He (V/V)	95	99.8	99.99	99.995	99.995	99.995	99.995	99.995	99.995	99.995	99.995	99.995
WATER		NONE CONDENSED	34	17	7.5	3.5	7.5	3.5	9.0	2.0		
DEWPOINT °F			-60	-70	-80	-90	-80	-90	-78	-97		
HYDROCARBONS (CONDENSED)		NONE					0.5 (WT/WT)					
GASEOUS HYDROCARBONS (AS METHANE)				25	10	25	5.0	5.0	1.0			
OXYGEN				5.0	3				1.0	1.0		
ARGON								1.0				
NITROGEN				25	14	14	14	14				
NEON									39	14	14	14
HYDROGEN				5.0	5.0	3.0	1.0			1.0	3.0	3.0
CO_2								1.0				
CO												
USP	YES											
PERMANENT PARTICULATES												

NASA-S-67-456

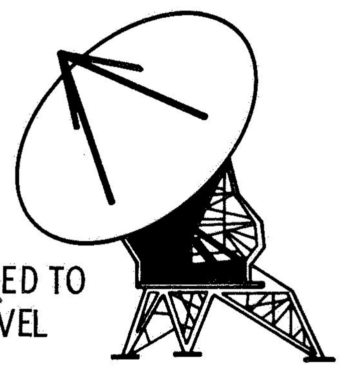
LHe APPLICATIONS



WITH OPERATION OF COMPONENTS IN A LIQUID HELIUM BATH, COMPUTERS CAN BE REDUCED FROM ROOM-SIZE TO DESK-SIZE



THE HIGH VACUUM REQUIRED IN SPACE SIMULATORS IS PRODUCED BY LIQUID HELIUM CRYO-PUMPING



LIQUID HELIUM IS USED TO REDUCE THE NOISE LEVEL IN MASERS

NASA-S-67-460

LHe SAFETY PRECAUTION(S)

AVOID CONTACT OF EITHER LIQUID OR COLD GASEOUS HELIUM WITH <u>ANY</u> PART OF THE BODY. WEAR RECOMMENDED PERSONAL SAFETY EQUIPMENT TO PROTECT EYES, HANDS AND SKIN FROM CONTACT WITH LIQUID OR COLD GAS.

NASA-S-67-461

LHe SAFETY PRECAUTION(S)

KEEP AIR AND ANY OTHER GASES AWAY FROM LIQUID HELIUM; THE LOW TEMPERATURE CAN SOLIDIFY ANY OTHER GAS, AND PLUGGED CONTAINERS MAY RESULT.

LHe SAFETY PRECAUTION(S)

PRESSURE-RELIEF DEVICES MUST BE ADEQUATELY SIZED. LIQUID HELIUM VAPORIZES VERY RAPIDLY WHEN HEAT IS INTRODUCED. THE PRESSURE-RELIEF DEVICES FOR LIQUID HELIUM CONTAINERS AND EQUIPMENT MUST HAVE SUFFICIENT CAPACITY TO RELEASE THE RAPIDLY EXPANDING HELIUM GAS SAFELY IN CASE OF HEAT INFLUX THROUGH INSULATION VACUUM FAILURE.

NASA-S-67-455

LHe SAFETY PRECAUTION(S)

RELIEF VALVES MUST BE PREVENTED FROM FREEZING OPEN.

THE OPEN VALVES WILL ALLOW THE CONTAINER TO BLOW DOWN AND EVENTUALLY AIR WILL BACKFLOW INTO THE CONTAINER WITH RESULTANT FREEZING.

LHe SAFETY PRECAUTION(S)

THE EXISTENCE OF A PRESSURE ABOVE ATMOSPHERIC IN A HELIUM CONTAINER DOES NOT ENSURE THAT BACK DIFFUSION OF AIR INTO COLD NECK TUBES WILL NOT OCCUR. CONTAINERS SHOULD BE CHECKED PROMPTLY UPON RECEPTION AND PERIODICALLY THEREAFTER TO BE SURE THE VENT PATHS ARE UNOBSTRUCTED.

NASA-S-67-451

LHe SAFETY PRECAUTION(S)

AFTER REMOVAL OF THE TOP FITTING OF A CONTAINER, VERY COLD HELIUM GAS WILL VENT. WHILE IT IS IMPORTANT TO CAP OR SEAL THIS CONTAINER RAPIDLY, CARE MUST BE EXERCISED TO PREVENT BURNS ON THE HANDS FROM THE COLD GAS. THE SOONER THE SEAL IS EFFECTED, THE BETTER BECAUSE THE ENTIRE TOP WORKS WILL RAPIDLY BECOME VERY COLD AND FROSTED, MAKING SEALING MORE DIFFICULT.

NASA-S-67-453

LHe SAFETY PRECAUTION(S)

BECAUSE AIR WILL CONDENSE ON LIQUID-HELIUM COOLED SURFACES, SUCH AREAS MUST BE CLEANED TO OXYGEN-CLEAN STANDARDS TO PREVENT POSSIBLE IGNITION OF GREASE, OIL, OR OTHER COMBUSTIBLE MATERIALS.

NASA-S-67-91

SUPERCONDUCTIVITY

THE PHENOMENA BY WHICH SOME SUBSTANCES SUDDENLY LOSE ALL ELECTRICAL RESISTANCE WHEN THEIR TEMPERATURES ARE REDUCED. (THESE TRANSITIONS OCCUR AT TEMPERATURES LOWER THAN THAT OF LIQUID HYDROGEN)

NASA-S-67-89

SUPERCONDUCTORS

METALS AND COMPOUNDS
(TRANSITION TEMPERATURE IS EXPRESSED IN K)

TITANNIUM	0.53
CADMIUM	0.56
ZIRCONIUM	0.70
URANIUM	0.80
ZINC	0.91
ALUMINUM	1.20
THORIUM	1.39
THALLIUM	2.38
INDIUM	3.37
TIN	3.73
MERCURY	4.15

NASA-S-67-95

SUPERCONDUCTORS
(CONTINUED)

TANTALUM	4.4
VANADIUM	5.1
LEAD	7.22
COLUMBIUM	8
TECHNETIUM	11.2
Nb_3Sn	18
NaBi	2.2
Mo_3Re	10.5
LiBi	2.5
PbAsBiSb	9.0
WOOD'S METAL	8.2

APPENDIX I

1. Suggested lesson-plan guide accompanied by notations to the instructors

2. Suggested session quiz and related answer sheet

3. Selected support materials including "Versatile Carbon Dioxide," opaque projection materials, and transparencies

Suggested Lesson Plan

for

Session 9

CARBON DIOXIDE

AND

THE RARE GASES EXCLUDING HELIUM

Estimated Time	Item(s)
	1.0 Announcements and review of the preceding session
0005	1.1 Announce the deadline due dates for each of the following. a. Course appraisal sheets b. Quiz items (optional) c. System design layout
	1.2 Review the preceding session
	2.0 Objectives for carbon dioxide and the rare gases
0010	2.1 Present the session objectives including the following. a. To become familiar with the characteristics and properties of carbon dioxide and the rare gases including argon, krypton, neon, and xenon b. To become further aware of how these gases are produced and their potential use, especially at this Center c. To become more knowledgeable about hazards and safety measures which pertain to liquid carbon dioxide (LCO_2), liquid argon (LA), liquid krypton (LKr), liquid neon (LNe), and liquid xenon (LXe)

Estimated Time	Item(s)
	3.0 Overview of the rare gases
	3.1 Provide a brief overview of the rare gases, including the following. a. The discovery of these gases during the short time period from 1894 to 1898. b. Information on rare gas discoveries which aid in understanding the periodic table c. The fact that the discovery of these gases led the way to modern concepts of chemical-bond formation in terms of loss or gain of electrons
0025	3.2 Review, using graphics display S-67-35693, the extremely small percentage of the atmosphere which these elements comprise.
	4.0 Characteristics and properties of rare gases
	4.1 Use the chalkboard, the flip chart, and so forth to present those characteristics common to the rare gases such as the following. a. Monatomic structure b. Chemical inertness c. Ionization at very low voltages d. Qualities of being colorless, odorless, and tasteless e. Emission of brilliant, distinctive, colored light
	4.2 Use transparency S-67-4615 to compare the boiling points of these liquids.
	4.3 Use transparency S-67-4753 to show the gaseous expansion ratios for each of these gases and to compare each with nitrogen, oxygen, hydrogen, and helium.
0035	4.4 Compare the respective densities of LA, LKr, LNe, and LXe with the density of water, by using transparency S-67-4752.

Estimated Time	Item(s)
	5.0 Production of rare gases
	5.1 Review briefly the fractional-distillation process used for LN_2 and LOX.
	5.2 Show transparency S-67-153 and briefly explain the process for separating the rare gases from the atmosphere.
0045	5.3 Discuss the fact that the rare gases require more elaborate processing than LN_2 or LOX.
	6.0 Hazards and safety measures
	6.1 Discuss the potential hazards involved in use, handling, and storage of the rare gases.
	6.2 Project (write on the chalkboard) the general safety measures concerned with rare gases.
0055	6.3 State that at the present time, the rare gases are not covered by the MSC Safety Manual (MSCM 1700), but that a "standard" is in the process of being prepared.
	7.0 Uses of rare gases, especially at this Center
	7.1 Point out some of the places that rare gases are used at the Center and the purposes for which each is used.
0105	7.2 Obtain from the class participants some industrial and related uses of these gases and add several additional uses and applications as appropriate.
0115	C L A S S B R E A K
	8.0 Carbon dioxide
	8.1 Present a brief overview of carbon dioxide (see "Versatile Carbon Dioxide" in appendix I).
	8.2 Obtain from class participants some examples of the almost limitless uses made of carbon dioxide. Supplement class contributions as appropriate. (It may be advisable to list these uses on the chalkboard.)

Estimated Time	Item(s)
	8.3 Point out, using S-67-20407 ("Aerial View of the Manned Spacecraft Center") the locations and the uses of CO_2 at this Center.
	8.4 Use transparencies S-67-570 and S-67-571 in discussing the characteristics and properties of CO_2. (Insure that the meaning of triple-point is understood.)
	8.5 Discuss the production of CO_2 briefly. Show transparency S-67-579 concerning the liquid CO_2 system.
	8.6 Discuss the hazards and safety precautions which pertain to carbon dioxide. Show transparency S-67-575 for safe handling of CO_2 (taken with solid CO_2), transparency S-67-4751 (taken with bulk liquid containers), and transparency S-67-4750 (liquid container handling precautions).
	8.7 Stress the safety measures to be taken with CO_2 containers (cylinders, tubes, tanks, and so forth) used at the Center. Show transparency S-67-17861 and explain the use of CO_2 for fire fighting purposes at this Center.
0145	8.8 Discuss the shipping and storage of CO_2 at the Center.
	9.0 Session assessment
	9.1 Administer the quiz.
0155	9.2 Discuss the quiz items.
	10.0 Summary and distribution of handout materials
	10.1 Summarize salient session highlights and announce the topics for next session.
0200	10.2 Distribute the handout materials to the class participants.

Session 9 Quiz

A. Multiple Choice

___ 1. What are four rare or inert gases?

a. Hydrogen, helium, argon, and neon
b. Helium, oxygen, krypton, and argon
c. Argon, krypton, neon, and helium
d. Argon, oxygen, helium, and xenon
e. Krypton, argon, helium, and hydrogen

___ 2. Argon exists in the atmosphere in concentrations of ______ to ______.

a. 0.001 to 0.05 percent
b. 0.10 to 0.32 percent
c. 0.41 to 0.63 percent
d. 0.71 to 0.79 percent
e. 0.80 to 0.93 percent

___ 3. The extremely rare atmospheric element krypton comprises (in volume) approximately ______ millionth(s) of the atmosphere.

a. One
b. Fifty
c. One hundred
d. Five hundred
e. One thousand

___ 4. Which of the following statements is true of all rare and inert gases?

a. Explosive and dangerous
b. Colored and explosive
c. Easily liquefied in explosive form
d. Easily solidified in explosive form
e. Colorless and odorless

___ 5. If liquid argon comes into contact with the skin, what first-aid treatment should be administered immediately?

a. Apply petroleum jelly
b. Apply bandages
c. Apply hot compresses
d. Apply compresses — first; bandages — second
e. Apply cold water

___ 6. Who was the English chemist who discovered neon in the year 1898 while studying liquid air?

a. Boyle
b. Charles
c. Ramsay
d. Powell
e. Roentgen

Session 9 Quiz (cont'd)

___ 7. Should excessive spillage of argon occur in a confined working area, what procedure should be followed prior to entering the area?

a. Enter the area as soon as the door can be opened.
b. Enter the area only if equipped with an operating life-support system.
c. Actuate the nearest fire alarm.
d. Spray the area with water.
e. Spray the area with foam or a dry chemical.

___ 8. Argon gas is used extensively in fabricating processes to provide which of the following?

a. An inert gas shield in arc welding
b. A blanket to protect the welding flame
c. A means of keeping the metals that are to be welded together clean
d. A gas coolant to assist the welder
e. Leak detection in tanks subjected to high pressures

___ 9. What is the color emitted from a neon light without any other element added to the neon?

a. Blue
b. Green
c. Scarlet
d. White
e. Lilac

___ 10. What is the major safety consideration in handling a full rare- or inert-gas cylinder when attaching a regulator to the valve outlet?

a. Assume that the threads on each are the same.
b. Assume that the outlet is clean and that a tight seal has been obtained to prevent the release of high-pressure gas which could be dangerous.
c. Hold the cylinder securely in place.
d. Assume that the cylinder contains a high-pressure gas and that proper safety precautions must be followed.
e. Assume that the gas is low-pressure and therefore the cylinder should be in a horizontal position.

B. True or False

___ 1. Carbon dioxide is an inert, colorless, odorless gas.

___ 2. Neon exists in the atmosphere in the proportion of 18 parts per million.

___ 3. Carbon dioxide gas is lighter than air.

___ 4. The light from a neon lamp is so intense that it can be seen in the daylight nearly as well as it can be seen at night.

Session 9 Quiz (cont'd)

___ 5. Argon gas is heavier than air (Sp. Gr. = 1.38) and tends to flow into low-lying areas.

___ 6. Neon is used in tubes and in lamps for purposes such as advertising, airport beacons, and so forth.

___ 7. The liquid-to-gas expansion ratio for one cubic foot of liquid krypton is 705 cubic feet of gas at normal pressures and temperatures.

___ 8. Neon gas is readily available and is relatively inexpensive to purchase.

___ 9. Xenon is sold commercially in small glass bulbs with thin walls and in cylinders.

___ 10. Neon is separated from the elements comprising atmospheric air by liquefying the air at approximately -200° C.

Session 9 Answers

A. Multiple Choice

1. c
2. e
3. a
4. e
5. e
6. c
7. b
8. a
9. c
10. d

B. True or False

1. True
2. True
3. False
4. True
5. True
6. True
7. True
8. False
9. True
10. True

VERSATILE CARBON DIOXIDE

Remarks by W. R. Wiggins, Jr.

Carbon dioxide is one item about which we learn something new every day. This is one of the oldest known gases as far as man's knowledge is concerned. It was first recognized as a chemical compound by a Belgian chemist in 1640. The French scientist Lavoisier determined its exact composition in 1774 and called it carbonic gas. Since 1888, carbon dioxide has been produced commercially. It was the first gas to be compressed and sold in this country in steel bottles on the commercial market. The chemical symbol is CO_2 and its molecular weight is 44.01.

Carbon dioxide really is one of the keystones in life on earth. Animals exhale carbon dioxide and plants breathe carbon dioxide and then convert it back to oxygen, which, of course, helps keep oxygen in supply for animal life. This process in plant life we know as photosynthesis — a continuous conversion process. Since all living plant life requires carbon dioxide and all animal life requires oxygen, a perfect balance is established. (Somebody really knew what they were doing when they set this process in motion.) Carbon dioxide is generally classed in industry as an inert gas although in school our chemistry professors always insisted that at 3000° F, it begins to break down — but not too many of us are worried about 3000° F. CO_2 is relatively stable and relatively inert unless its temperature is excessively high. In fact, the percent of break down even at 3000° F is less than one percent of disassociation. Carbon dioxide can exist as a liquid, gas, or solid under the normal conditions encountered every day. At seventy-five pounds pressure and 70° F, all three conditions can exist. This is known as the triple point for carbon dioxide. Above 88° F, however, you cannot convert CO_2 into liquid state regardless of the pressure applied. This, of course, is the critical temperature. Though carbon dioxide was sold in steel cylinders as early as 1888, it is usually sold today in either rail tank cars or in tank trailers.

Industry, incidentally, is continuously plagued by highway patrolmen stopping CO_2 trailers because of a fire somewhere nearby. These patrolmen do not want a gasoline tank or any type of tank truck there. Most of the people involved with traffic enforcement seem to think of CO_2 as being dangerous and inflammable. Actually, there have been recorded instances where CO_2 trailer drivers were sharp enough to pull up to the vehicle on fire, unhook their hoses, and spray liquid CO_2 on the flame and extinguish it. However, in most instances this could be done only after fighting the fire department to let them get the "job done." Firemen thought the CO_2 drivers had compressed gas and, therefore, should not get within a mile of the fire. Actually, the CO_2 tank truck is really a rolling fire extinguisher going down the highway. However, these trucks are prohibited from going through tunnels because there is a policy that no tank trailers can go through. . . which is, in general, a good, safe policy to follow.

The carbon dioxide industry in 1900 was selling about a million pounds per year in the United States. By 1965, industry was selling over a billion pounds per annum and the Stanford Research Institute predicts that this will double again by 1975. Generally, the carbon dioxide industry has been controlled primarily by four major industries during the past fifty years, but this situation was finally changed by the Justice Department.

One of the uses of CO_2 that might be of interest to you at the Center includes the inflation of life rafts for use in manned space flight recovery operations. CO_2 is used because it's safe, more cubic feet of it can be placed in a bottle than nitrogen or some of the other gases, and, of course, it is more economical. CO_2 is one of the most versatile tools in the gas industry. Several thousand applications are known today for carbon dioxide use. Uses vary from carbonating soft drinks to preserving the aroma in instant coffee where the carbon dioxide is used as a solvent, and from use as a refrigerant in an oil refinery to packaging all sorts of foods including cheese, meats and coffee. Most of you are familiar with carbon dioxide as a fire fighting medium. Electronic data processing systems are sometimes protected with carbon dioxide systems because they can extinguish a fire and not leave a "mess" afterwards. Carbon dioxide is also used in greenhouses to stimulate plant growth where normal plants receive carbon dioxide from the air. By controlling the atmosphere in a greenhouse and increasing the carbon dioxide concentration, it is possible to obtain yields of more than 1000 percent greater than the normal growth attained in plants such as tomatoes, orchids, and all sorts of plant life that commercially requires a controlled atmosphere. Unfortunately, in this part of the country our greenhouses get so hot that by midday, ventilation is necessary. However, further north, where greenhouses are closed upward to five months of the year, CO_2 works beautifully.

Carbon dioxide was, according to some of the cryogenic engineering booklets, the first known cryogenic material. Today I don't think many people consider it as a cryogen because it liquifies and turns to solid even at -190° F. Actually, temperatures down to -150° F can be obtained by using carbon dioxide. Early environmental test chambers used carbon dioxide because it was available and it was cheap. It has a lot of built-in refrigeration, more per pound than nitrogen does even though the temperature is not as cold. For example, 245 Btu per pound can be obtained from solid carbon dioxide and 130 Btu from liquid carbon dioxide as compared with 76 Btu from liquid nitrogen. Many of the aircraft companies use carbon dioxide for obtaining low temperatures for honeycomb.

Carbon dioxide is used in surgery for anesthesia purposes so that the motor will continue to run when carbon dioxide is not in the lungs, or, of course, breathing stops; this is the thing that makes you breathe. One safety point of interest is this — should you ever have to get into a chamber or room where carbon dioxide system has been discharged, there is no question as to whether there is too much carbon dioxide because you will be puffing and breathing just as if you were at a 20 000 foot mountain elevation and had just run four miles. This much concentration of CO_2 will make your diaphragm work harder to expel CO_2 and therefore you breathe deeper and more rapidly. This rapid and deeper breathing is the first sign that one would have in a compartment, a tank, a tank space, the hold of a ship, or anywhere else where there is too much CO_2. About 3 percent is as much as one can

safely tolerate. Above this, of course, one has difficulty breathing, and this could not be done very long as you would be worn out just as if you were mountain climbing and not getting enough oxygen. CO_2 is not toxic though many people tend to confuse carbon dioxide with carbon monoxide. Since carbon dioxide is not toxic, it is used in some of the larger meat packing plants for painless slaughter of animals. Pigs and lambs, generally, are the only animals on which CO_2 is used because cattle will instantly raise their heads "up and over" the blanket of CO_2. A trough arrangement is on the chute where the animals come down, and in as much as sheep and hogs have their noses close to the floor, they readily breathe CO_2. Within 35 to 50 seconds exposure time in a CO_2 atmosphere, these animals fall over asleep. Though the CO_2 does not kill them, it "knocks them out." The Department of Agriculture inspectors will sample animals passing through to make sure they are not giving them too much and not actually suffocating them and just putting them to sleep. There is no permanent damage, but it does immobilize and anesthetize the animals.

One of the largest and oldest uses for carbon dioxide, of course, is in making aspirin or salicylic acid, where the carbon dioxide is used as a chemical.

Carbon dioxide is also used as a coolant. Several years ago, while trying to build jet engines out of titanium, the contractor was having a difficult time machining titanium. They were burning up tools and the rejects were running something like 40 percent. The titanium blank for just one of these turbine wheels was about $4000 from which the scrap value was only $122 per pound. This problem was solved by using carbon dioxide as a coolant in the machining and grinding of titanium. It is still used where conventional coolants just cannot do the job and where it is desired to improve the tool life by using CO_2 as a coolant in dressing these tools rather than placing them in oil or emulsion type of coolant. CO_2 can sometimes double or triple the life of a tool which more than offsets the cost of the carbon dioxide. Some grinding and machining operations necessitate keeping the work cool and the tool cool with a real fine jet, say six-thousandths or ten-thousandths of an inch nozzle-hypodermic needle tubing tool is what is used for this work. Liquid CO_2 is sprayed on the work to keep the work clean, the grinding wheel clean, and prevents the grit from "riding over and over again" in the oil. Consequently, better finishes are obtained as well as more accurate tolerances.

Carbon dioxide is used in the preparation of cake and pie mixes where shortening is mixed with flour, sugar, and salt, and other ingredients. Yesteryear your mother probably chopped up ice or used ice water to prevent shortening from becoming gummy and messy. In preparing mixes today for packaging, liquid CO_2 is sprayed into the mixes. Ribbon blenders are used for these mixes where the ingredients are mixed with a rotating ribbon type blade. This serves to keep the whole mixture cooked, keeps the air away from it, and of course, prevents oxidation while simultaneously obtaining a much more uniform mix or blend. Uniformity helps make today's cake and pie mixes much tastier than they were years ago.

CO_2 is also used, of course, to make acetic acid, ethylene carbonate, and polyethylene. It is also used to make high purity carbon monoxide. Carbon dioxide (monoxide) is generally considered a good "building block" in the chemical industry.

CO_2 is used as a nontoxic method of rodent control in grain elevators and cold storage plants. In cheese warehouses once plagued with rats it was necessary to remove all the cheese and then fumigate the entire building with cyanide or a comparable chemical and then ventilate before re-entering the building. Now carbon dioxide is placed in warehouses on Friday afternoon and on Monday morning the dead rats are merely picked up. You don't even have to move the cheese today.

CO_2 has been used in truck and railroad car refrigeration as dry ice. However, dry ice is phasing out and being replaced by new liquid systems that spray controlled amounts of liquid CO_2 through a nozzle as indicated by a temperature controlled thermostat. For certain foods carbon dioxide is beneficial and for others it is not. Take strawberries for example. Nearly all fresh strawberries are shipped with the help of CO_2 because it helps prevent mold (or whiskers as it is known in the industry) from growing on strawberries. A carbon dioxide atmosphere in a railroad car will yield an additional $400 to $500 for a carload of strawberries sent from New Orleans to Chicago because they arrive in much better condition. In this instance CO_2 is not used as a coolant, but as an atmosphere to prevent the growth of bacteria . . . in the form of mold.

An interesting use for carbon dioxide is in the manufacture of silicone dials such as those produced by Texas Instruments. On these little wafers an entire printed circuit can be placed on approximately the size of a quarter, but with the thickness of a piece of paper. However, it was difficult to mill these wafers. They are milled on a miniature milling machine just like a big piece of machinery, but of course, under a microscope. Holding these small wafers while the machine cut the circuits was proving a problem, so a method using flat stainless steel (called a "chuck") was devised. The wafer goes beneath this stainless steel chuck as a jet of liquid carbon dioxide is sprayed by means of a foot control valve. The water is frozen and holds the wafer and the circuits are machined onto it. A warm jet of air on the underside thaws out the wafer so that it can be picked off without slipping. This one use requires 2 000 000 pounds of carbon dioxide a year, but this is a relatively cheap process for Texas Instruments since it does the job for which a million dollars was spent on its development alone.

Carbon dioxide is used in deflashing molded rubber parts ranging from the heels on your shoes to a hundred different items on automobiles, O-rings, and so forth, where these pieces are molded onto big sheets. Pieces are placed in a tumbling barrel and by spraying carbon dioxide into this tumbling barrel the temperature is decreased to -100° F, which embrittles the flash or thin sections of rubber and in "the tumbling" they break off — a process which once required trimming by hand. Now this is done in a matter of minutes by just tumbling at cold temperatures. where Buna compounds exist, thereby precluding freezing at -100° F, it is first cooled the first 100° with CO_2, then liquid nitrogen is injected to further decrease the temperature to the point where the flash will get stiff and break off.

Carbon dioxide is used on barge and tanker inerting. When repair work on a barge, tanker, or a tank farm is needed, the system can be inerted with carbon dioxide, leaks welded, and other work can be performed which normally would necessitate steam cleaning and drying out. One safety problem in this procedure is making certain that static is not generated while inerting this tank. One firm in New Orleans a few years ago decided they would try this inerting process. With a line from a CO_2 trailer, liquid was sprayed into the barge, but they didn't realize that they were forming dry ice snow in the line. Unfortunately, these solid particles passing through the pipe started generating a good charge, and, of course, before they ever got the barge inerted, sparks caused an explosion. Gas, not solid particles, must go through a line to avoid generating any static.

Carbon dioxide is being used quite a bit these days as a shielding gas in welding carbon steel. This is nothing new. A major manufacturer got a patent on this in 1903, but nothing was ever done with it until about 10 years ago. Now, it is used for pH control in waste disposal. If there is any waste caustic that should be neutralized before it is dumped, the pH can be lowered by either throwing dry ice in a tank or settling basin, or by injecting carbon dioxide liquid or gas into it. Caustic has a great affinity for CO_2 and neutralizes quickly. Moreover, it is safe.

In oil well operations carbon dioxide has many applications. You've probably heard more about nitrogen because nitrogen has been used to advantage in this area. One company has done a tremendous job in developing nitrogen in oil well servicing, principally because there is no carbon dioxide available for this work; quite a few wells on the West Coast and in Mississippi have used carbon dioxide for various jobs — "clean outs," acidizing, stimulations, etc., where CO_2 combines with the water making a mild acid. CO_2 dissolves the lime and calcium formations which nitrogen, of course, only pressurizes. This is a field that several years from now may be using more carbon dioxide than all the soft drink bottlers in the world.

Carbon dioxide is used to treat water by neutralizing excessive alkalinity. The city of Minneapolis is, perhaps, the largest user, due to its hard water situation. However, CO_2 is used, too, in many areas for pH control and better drinking water.

One thing that the early scientists discovered pertained to mineral springs. For centuries mineral springs around the world were known to have some value in human consumption. The only things these mineral springs had in common were water and carbon dioxide. The degree of calcium, lime, iron, and sulphur, all vary from one spring to another, but all had carbon dioxide. The most famous ones, the Carlsbad, and those located at Hot Springs, French Lick, White Sulphur, et cetera, have a high percentage of carbon dioxide and today most of these hotels buy carbon dioxide and add a little more to their springs.

In 1955, a use for CO_2 was introduced to this country by Germany's Dr. Schumacher, who came to Houston in 1955 to the American Foundry Convention to discuss a process which had been developed for making sand cores and molds without baking. By using sodium silicate and sand and exposing them to carbon dioxide, the combination hardens like concrete. A process which once took hours now takes minutes and foundries throughout the world are adopting this process.

CO_2 is mixed in the aerosol packaging of certain food stuffs. It is used in a mixture of nitrous oxide for whipped cream. If you used carbon dioxide alone, the whipped cream would have too sharp a taste. When CO_2 is used in a 15-85 mixture with nitrous oxide, which of course has no taste, the mixture is very effective and considerably less expensive, but nitrous oxide is many times more costly than carbon dioxide.

Liquid CO_2 is used as a refrigerating medium in curing. The solid fuel rocket propellants, used by one of the largest carbon dioxide consumers in the state of Texas, use CO_2 to maintain uniform temperatures and at the same time an inert atmosphere in these curing chambers of the solid fuel units.

Carbon dioxide has also been used for such wild things as trying to cool off a lake at Tullahoma, Tennessee. At Tullahoma, nine trailerloads of CO_2 were injected into a 40-inch water line down in the wind tunnel. Though the idea worked, it proved too expensive, but serves to illustrate the fact that every day something comes up.

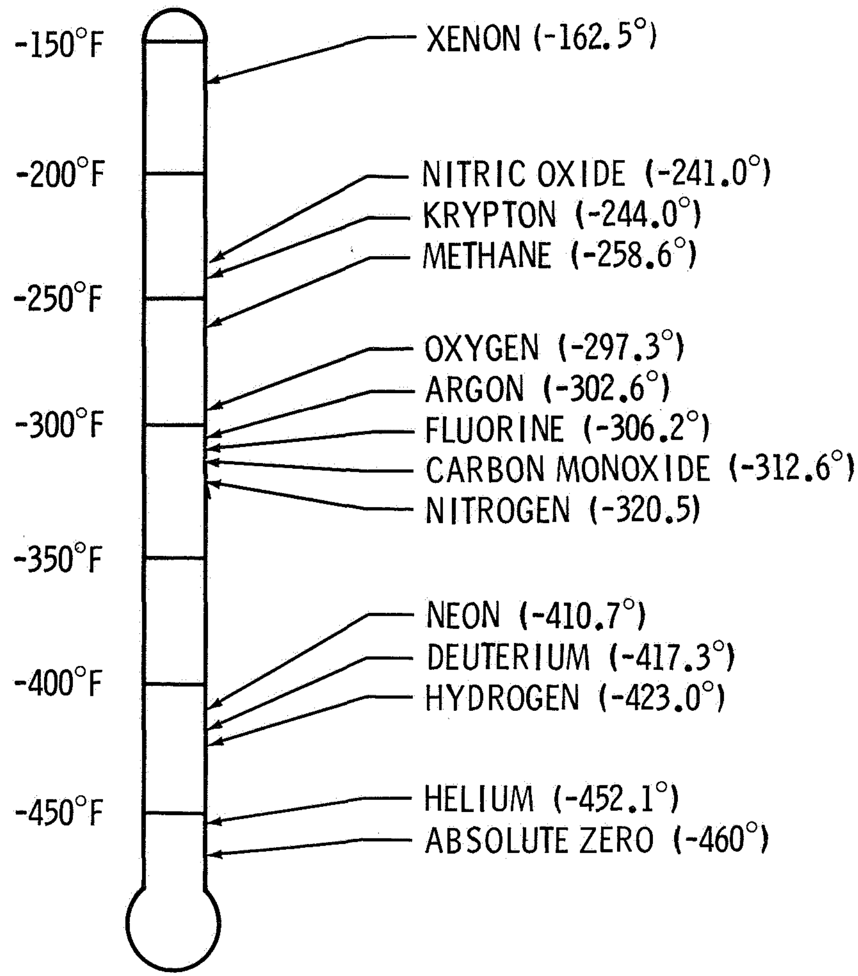
It is also used in re-entry simulation, wind tunnel work, and controlled atmosphere studies where they want to get certain densities and temperatures. It is real easy to inject liquid CO_2 and take advantage of refrigeration value.

The uses of carbon dioxide are countless. But its use and potential for space application is tremendous as we know. CO_2 is, and will continue to be, a most versatile product which can and will be used to benefit mankind.

W. R. Wiggins, Jr.
President, Southwest Cryogenics
Houston, Texas

NASA-S-67-4615

HERE'S HOW THE NORMAL BOILING POINTS OF CRYOGENS COMPARE



NASA-S-67-4753

'LIQUID TO GAS EXPANSION RATIOS'

USING 1 CU FT OF LIQUID RAPIDLY PRODUCES
TREMENDOUS GAS VOLUMES*

LA = 841

LKr = 693

LNe = 1,445

LXe = 558

*EXPANSION RATIOS TAKEN FROM VEST POCKET HANDBOOK,
AIR REDUCTION CO, INC,
PAUL DIVISION, (UNDATED)

NASA-S-67-4752

APPROXIMATE LIQUID TO WATER DENSITY RATIOS*

LA = 1 1/2

LNe = 1 1/4

LKr = 2 1/4

LXe = 3

*DENSITY RATIOS TAKEN FROM VEST POCKET HANDBOOK,
AIR REDUCTION CO, INC,
PAUL DIVISION, (UNDATED)

NASA-S-67-570

CO_2 PHYSICAL CONSTANTS

- MOLECULAR WEIGHT 44.004
- CRITICAL TEMPERATURE (T_C)
  - °C 31.0
  - °F 87.8
- CRITICAL PRESSURE (P_C), ATM 72.80
- TRIPLE POINT
  - °C .... -56.6
  - °F .... -69.9
- NORMAL SUBLIMATION POINT
  - °C .... -78.52
  - °F .... -109.33
- LATENT HEAT OF SUBLIMATION (BTU'S / LB) AT -109.33° F 246.25
- VAPOR PRESSURE OF SATURATED LIQUOR (PSIA) AT 0° F 305.8
- LATENT HEAT OF VAPORIZATION (BTU'S / LB) AT 0° F 120.0
- DENSITY (LBS / CU FT)
  - OF SOLID AT -109.33° F 97.59
  - OF SATURATED LIQUID AT 0° F 63.65

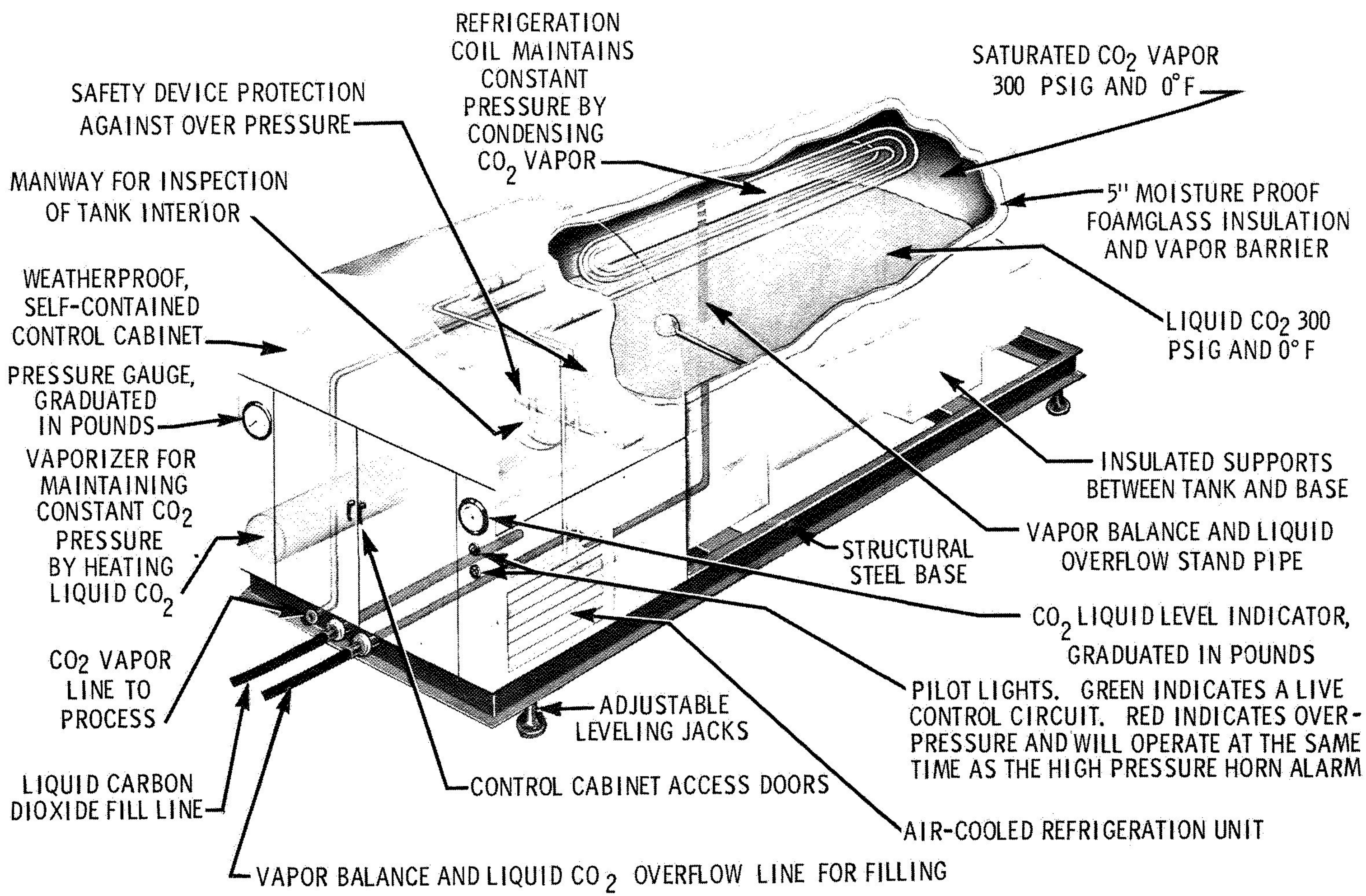
NASA-S-67-571

CO_2 PHYSICAL CONSTANTS (CONT)

- SPECIFIC VOLUME (CU FT / LB)
  - OF SATURATED GAS AT 0° F 0. 2905
  - OF SUPERHEATED GAS AT 70° F, 1 ATM 8. 79
- SPECIFIC HEAT (BTU'S / LB / °F)
  - SOLID (BETWEEN -110°F AND -70°F) 0. 378
  - LIQUID (BETWEEN -20°F AND 20°F) 0. 510
  - GAS AT CONSTANT PRESSURE (C_p)
    - AT 1 ATM; BETWEEN -110°F AND 0°F 0. 190
    - AT 1 ATM; BETWEEN 0°F AND 70°F 0. 198
  - GAS AT CONSTANT VOLUME (C_v)
    - BETWEEN -110°F AND 0°F 0. 143
    - BETWEEN 0°F AND 70°F 0. 151
- THERMAL CONDUCTIVITY OF THE GAS, (BTU'S / HR) (SQ FT) (°F / FT)
  - AT -109. 33 °F 0. 006165
  - AT 32 °F 0. 008215

NASA-S-67-579

L.P. LIQUID CO_2 SYSTEM



SOLID CO_2

- SOLID CO_2 IS EXTREMELY COLD (110°F BELOW ZERO)
- DO NOT HANDLE WITH BARE HANDS OR PLACE NEXT TO BARE SKIN
- DO NOT TASTE OR PUT NEAR MOUTH
- DO NOT PLACE IN GLASS JARS OR BOTTLES OR OTHER CLOSED CONTAINERS
- DO NOT ENTER POORLY VENTILATED PLACES WHERE LARGE QUANTITIES OF DRY ICE ARE STORED

NASA-S-67-4750

BULK L P CO_2 LIQUID CONTAINER HANDLING PRECAUTIONS

- DO NOT USE CO_2 VAPOR WITHOUT A SUITABLY DESIGNED PRESSURE-REDUCING REGULATOR OF SUITABLE DESIGN
- ANCHOR LCO_2 HOSE PROPERLY TO PREVENT RECOIL
- PIPELINES SHOULD BE OF FABRICATED AND WELDED CONSTRUCTION USING HIGH PRESSURE STEEL PIPE OR COPPER TUBING
- TO PREVENT UNDUE PRESSURE BUILDUP, PROPER PROTECTION SHOULD BE PROVIDED BY SAFETY RELIEF DEVICES
- DISCHARGE LINES SHOULD BE PROPERLY GROUNDED
- WHEN LCO_2 IS USED IN A CONFINED AREA, A LIFE SUPPORT SYSTEM WILL BE AVAILABLE
- PROTECTIVE CLOTHING WILL BE WORN BY PERSONNEL HANDLING LCO_2

NASA-S-67-4751

BULK L P CO_2 LIQUID CONTAINERS

- SHOULD BE WELL INSULATED
- REQUIRE MECHANICAL REFRIGERATION TO CONTROL AND LIMIT INTERNAL PRESSURES AND TEMPERATURES
- WILL BE LOCATED IN AREA NOT TO EXCEED 110° F OR FALL BELOW 0° F
- REQUIRE CLEANLINESS OF SURROUNDING AREA
- WILL HAVE PIPING PROVIDED IN AN ENCLOSED AREA WHICH LEADS TO THE OUTSIDE WITH LOW POINT DRAIN TO PREVENT A BUILDUP OF HIGH CONCENTRATIONS OF CO_2 GAS

APPENDIX J

1. Suggested lesson plan guide accompanied by notations to the instructor(s)

2. Selected support materials, including transparencies and opaque projection materials

Suggested Lesson Plan

for

Session 10

NEW DEVELOPMENTS

AND

COURSE RÉSUMÉ

Estimated Time	Item(s)
	1.0 Topics and objectives for the final session
	1.1 Review the highlights of the preceding session and state the following objectives for this session: a. To discuss current and future developments in the compressed gas and cryogenic liquid fields b. To review the major objectives for the entire course and summarize safety and related aspects of compressed gases and cryogenic liquids c. To appraise the course from both content and instructional points of view d. To present course completion certificates and take a group photograph of the class members (optional)
0005	1.2 Have one or more class participants display and comment on his organized compilation of the course materials for future reference purposes (optional).
	2.0 New developments in the compressed gas and cryogenic fields
	2.1 Discuss compressed gas and cryogenic developments occuring both outside of and inside of the Center.
	2.2 Discuss articles on cryogenics such as those in Time, June 16, 1967, and Reader's Digest, May 1967. Display photographs S-67-60581 and S-67-60582 on life support systems using the bulletin board and/or the opaque projector. Discuss the portable

Estimated Time	Item(s)
	life support system and the portable ventilator. Demonstrate the life support systems.
0025	2.3 Present an overview of the Center-wide fire-safety-security policy.
	3.0 Résumé of presentations
	3.1 Review appropriate major course objectives presented at the beginning of the course for their significance.
	3.2 Recapitulate highlights of compressed gases such as O, N, A, He, H_2, Ne, Xe, Kr, CO_2, and others, and emphasize the safety aspects.
	3.3 Summarize the high points of cryogenic fluids, including LOX, LN_2, LH_2, LHe, LA, LNe, and LCO_2. Stress the aspect of safety.
0040	3.4 Reiterate the point that the approach taken in this course has been to correlate safety with the salient aspects of compressed gases and cryogenic liquids.
	4.0 Appraisal of course and instruction
	4.1 Explain the purpose of group appraisal of the content of the course and its instruction. Discuss how the "buzz session" can be used for this assessment.
0045	4.2 Have the group chairmen (selected earlier by their respective groups) meet with their respective groups for approximately 12 to 15 minutes.
0100	C L A S S B R E A K
	4.3 Have each subgroup present comments and recommendations within 5-minute time frames. (Have one, or preferably two, persons serve as recorders.)
	4.4 Hold a 3- to 5-minute comment, question, and answer session following the final subgroup presentation.

Estimated Time	Item(s)
0140	4.5 Have the class members submit written or individual course assessments, supplemental quiz items (optional), comments, suggestions (optional), and so forth.
	5.0 Presentation of certificates of award
	5.1 Have an MSC Safety Officer and other parties concerned make appropriate end-of-the-course remarks.
	5.2 Have an MSC Safety Officer and other appropriate officials present the certificates of award.
	5.3 Assemble the class members for a group photograph (optional).
0200	5.4 Adjourn the class.

Notations to the Instructor

1. Prior to class, or preferably at the preceding session, have each class subgroup of four to five members select a chairman. Meet with the chairmen selected and briefly explain the purpose of the "buzz session" for the final meeting.

2. The "buzz session," if used properly, can be very fruitful in obtaining constructive, beneficial criticism which may be useful in improving the course.

3. Obtain current information on life support systems.

4. New developments are continuing to occur in the gas-cryogen field. Among current developments are those found in the literature concerning doubling the current production of gases and liquids by 1972 or 1973, effects of the polar stream, increase in commercial food refrigeration, new electrolytic processes for generating oxygen aboard ship, and aircraft systems developments.

5. New audiovisual materials, especially new films or film clips, may be appropriate for this course session.

6. Arrange for a photographer to take a group photograph prior to class.

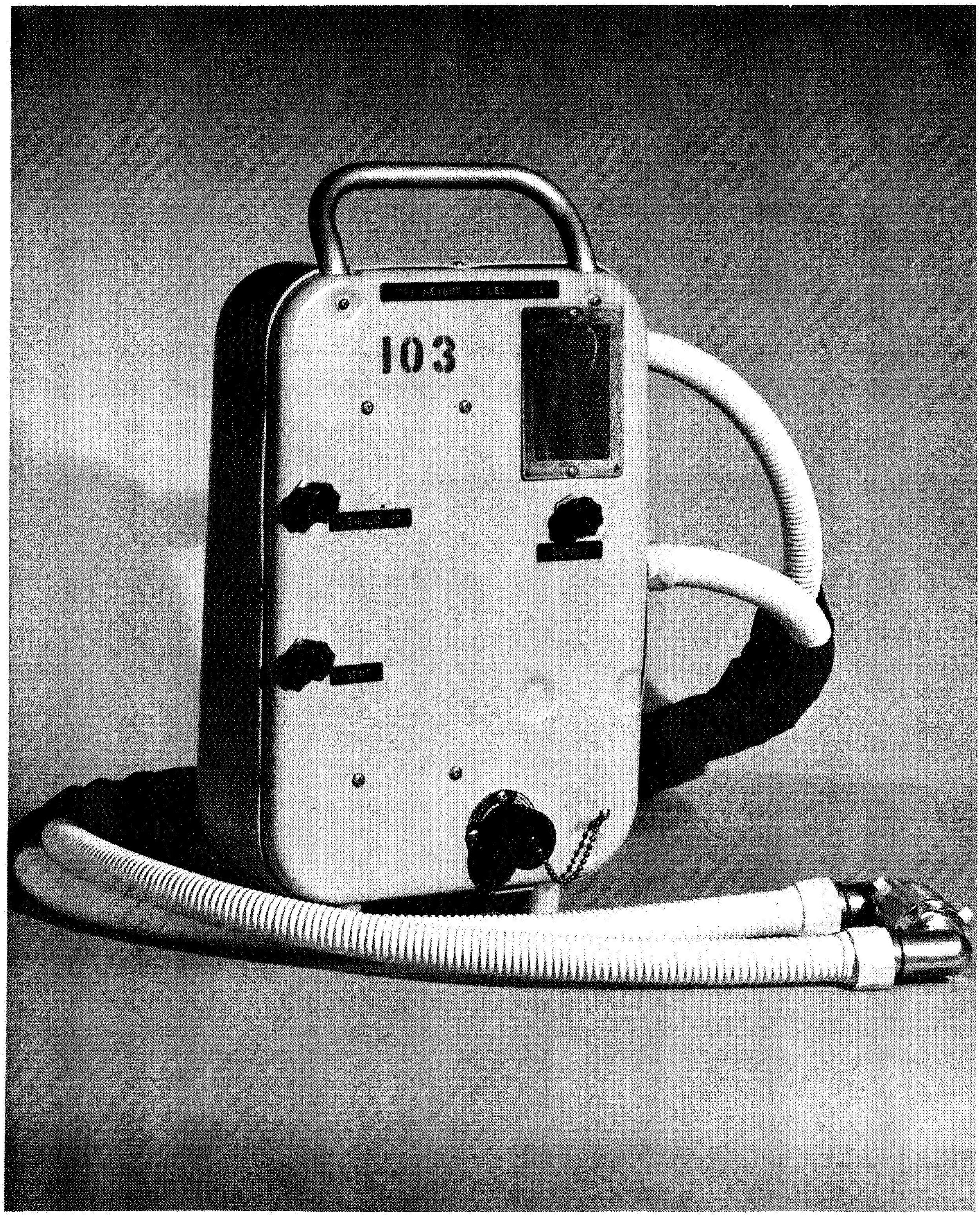
7. Prepare to distribute appropriate handout materials to the class participants.

8. Make prior arrangements to have certificates properly lettered and official signatures affixed ready for this session.

9. Arrange to have an MSC Safety Officer and other appropriate officials make remarks to the class as well as to present the individuals who successfully completed the course with certificates of award.

10. New developments and their respective applications will necessitate continual revision of this session. Among these developments are a cryogenics course and a new text on cryogenics. (Refer to reference material and printed matter.)

11. Arrangements should be made prior to class to have the appropriate materials, including audiovisual aids, available for review purposes.



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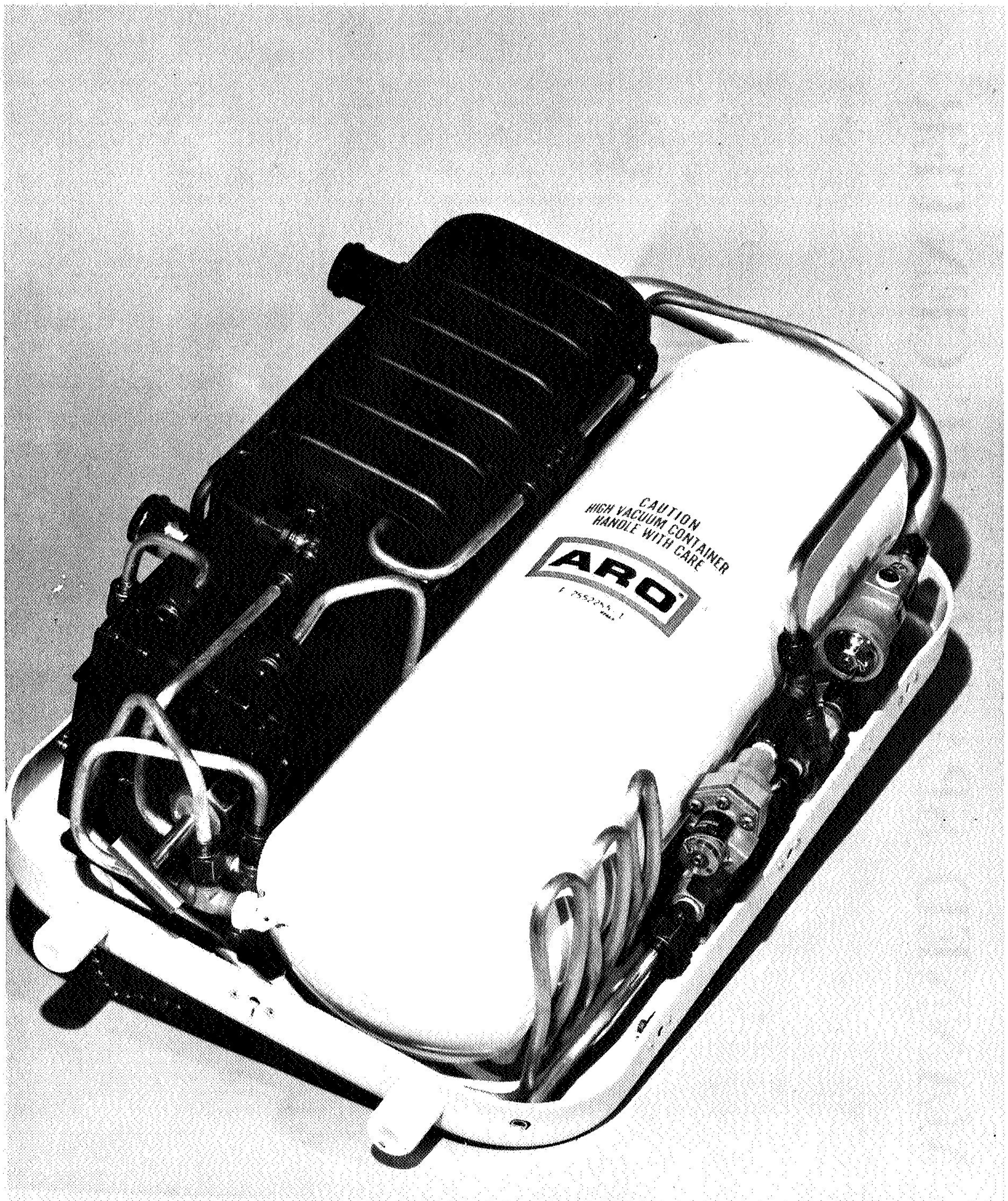

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MANNED SPACECRAFT CENTER

Certificate of Training

ROSS F. WORKMAN

has satisfactorily completed the

INDUSTRIAL GASES AND CRYOGENICS COURSE

of the

Manned Spacecraft Center

Given at Houston, Texas

FEBRUARY 10, 1967
DATE

NAME
ACTING, MSC SAFETY OFFICER

NAME
CHIEF, CREW SYSTEMS DIVISION

NASA-S-67-452

CURRENT CRYOGENIC RESEARCH

INCLUDES

- MEASUREMENT OF THE MECHANICAL PROPERTIES OF METALS
- STUDY OF SUPERCONDUCTIVITY OF SOLIDS SUCH AS SUPER-CONDUCTING MAGNETS
- INVESTIGATION OF THE NATURE OF NUCLEAR FORCES
- STUDY OF PHOSPHORS AND SEMI-CONDUCTORS FOR DETECTION OF INFRARED RADIATION
- INVESTIGATION OF THE PROPERTIES OF LIQUID He
- STUDY OF ELECTRONIC COMMUNICATIONS AND CONTROL PROCESSES
- INVESTIGATION OF CHEMICAL PROPERTIES OF MATERIALS
- STUDY OF FREE RADICAL CHEMISTRY
- INVESTIGATIONS IN SOLID STATE PHYSICS

APPENDIX K

Master Sensory Materials List

Among the audiovisual aids used to support this course are those including displays and exhibits, equipment, field trips, films, opaque projection materials, slides, transparencies, and so forth. Many of the aids used in this presentation of this course are described herein.

Displays and Exhibits.-

Type	Session
Display of printed and related material used in this course (to be prepared by instructor).	1
Pegboard display on "Over Pressure Safety Devices."	4
Metallic materials used with cryogenic liquids at the Manned Spacecraft Center.	5
Non-metallic materials used with cryogenic liquids at the Manned Spacecraft Center.	5
Mannequin and appropriate cryogenic suit materials for placement on mannequin.	7

Equipment.-

Type	Session
Three or more empty, though compatible, high-pressure cylinders (typical of those used at the Center).	
Dollies and/or an appropriate cylinder cart with wheels.	
Backpacks such as those manufactured by Mine Safety Appliance, Scott, SurvivAir, and so forth.	4,10
Dewar vessels of various sizes.	6
Protective clothing such as face shield, gloves, apron, and so forth.	6
Rubber tubing, ball, vegetables, fruit, lubricant, alcohol, and other materials.	6

Graphics Displays (30 by 40 in.).-

NASA Number	Title	Session
S-67-20407	Aerial View of Manned Spacecraft Center	2,5,7,9
S-67-35692	Atmospheric Layers and Manned Space Flight Penetrations	2
S-67-35693	Gaseous Content of Dry Air	2,5
S-67-35694	Air	2,5

Films.-

Title	Session
Working with Compressed Gases	3
Liquid Oxygen . . . Safe Handling and Storage	5
Oxygen-Nitrogen Generating Plant	6
Untitled silent film clip on oscillations and liquid helium	8

Opaque Projection Materials (photographic only).-

NASA Number	Title	Session
S-67-17850	28 000 Gallon LN_2 Storage Tank	6
S-67-17861	Special Hazards Vehicle	7,9
S-67-20077	Proper Cylinder Handling and Storage	3
S-67-20079	Transferring Liquid Nitrogen	6
S-67-20727	Safe Handling of Industrial Gases	3
S-67-29818	Central Gas Storage Facility	3
S-67-29819	Central Gas Storage Facility	3
S-67-35691	Using Compressed Gases	3
S-67-36437	Transferring LN_2	6
S-67-36439	View of Metallic Materials Used with Cryogenic Liquids	5
S-67-36443	Over Pressure Safety Devices Pegboard Display	4
S-67-36444	Display of Several Dewar-Type Storage Containers	6
S-67-36445	Safety Office Secretaries . . . Over-Pressure Safety Devices	4
S-67-36449	View of Nonmetallic Materials Used with Cryogenic Liquids	5
S-67-42417	Training Course Completion Certificate	10
S-67-44002	Repressurization Tanks for Space Simulation Chambers	4
S-67-60581	Typical Portable Ventilator	10
S-67-60582	A Portable Life Support System (PLSS)	10

Slides.-

Type	Session
Keeping Cylinders Safe	3
Liquid Hydrogen	7
Liquid Helium	8

Transparencies (in ascending numerical order).-

NASA Number	Title	Session
S-67-84	Atmosphere	2
S-67-85	Compressed Gas Cylinders	3,4
S-67-86	Compressed Gas Cylinders	3,4
S-67-87	Atmospheric Elements with Which MSC Is Particularly Concerned	3,5
S-67-88	Air	2,5
S-67-89	Superconductors	8
S-67-90	Oxygen — Safety in Handling	5,6
S-67-91	Superconductivity	8
S-67-4130	Some Instructional Techniques and Methods	1
S-67-4129	Course Coverage	1
S-67-95	Superconductors(cont'd)	5
S-67-96	Definition of Cryogenics	5
S-67-97	Atmosphere Chart	2
S-67-98	Properties of LOX	5
S-67-99	Properties of LN_2	6
S-67-152	Storage Tank Schematic	5
S-67-153	Separation of Industrial and Rare Gases from the Atmosphere	6,9
S-67-4614	Helium Specifications	8
S-67-155	Hydrogen — Safety and Handling	7
S-67-156	Safety in LOX Vessels	5
S-67-157	Diagram of Air Separation Cycle	6
S-67-158	Cryogenic Identification Standard for LOX	6
S-67-159	Cryogenic Identification Standard for LN_2	6
S-67-160	Photograph of LOX and LN_2 Identifications In Use	6
S-67-161	Photograph of Storage Tank with Safety Decal	6
S-67-450	LHe Safety Precautions	8
S-67-451	LHe Safety Precautions	8
S-67-452	Current Cryogenic Research	10
S-67-453	LHe Safety Precautions	8
S-67-454	Compressed Gas Association (CGA) Fittings	3
S-67-455	LHe Safety Precautions	8
S-67-456	LHe Applications	8
S-67-457	Session Objectives	5
S-67-458	Cylinder Size Chart	3
S-67-459	LHe Safety Precautions	8
S-67-460	LHe Safety Precautions	8
S-67-461	LHe Safety Precautions	8
S-67-462	Cryogenic Thermometer	5
S-67-569	Metals Suitable for Use with LH_2	7
S-67-570	CO_2 Physical Constants	9
S-67-571	CO_2 Physical Constants	9
S-67-572	LH_2 Characteristics	7

NASA Number	Title	Session
S-67-573	Nonmetals Suitable for Use with LH_2	7
S-67-574	LH_2 Characteristics	7
S-67-575	Solid CO_2	9
S-67-576	Materials Utilized with LH_2	7
S-67-577	LH_2 First Aid Notice	7
S-67-578	Potential Hazards in Handling LH_2	7
S-67-579	L.P. Solid CO_2 System	9
S-67-4128	Compressed Gas Cylinders	3
S-67-4346	LN_2 In Case of Accident	6
S-67-4347	LH_2 In Case of Accident	7
S-67-4969	Rigid Transfer Tube	7,8
S-67-4349	Flexible Transfer Tube	7,8
S-67-4350	LOX in Case of Accident	5
S-67-4351	High Altitude Chart	2
S-67-4352	Major Topics	1
S-67-4353	LN_2 (-320° F or 20° K)	6
S-67-4354	LH_2 (-423° F or 77.59° K)	6
S-67-4355	LOX (-297° F or 90° K)	5
S-67-4613	Compressed Gas Cylinders	3
S-67-4614	Helium Specification	8
S-67-4615	Comparison of the Normal Boiling Points of Cryogens	5,9
S-67-4616	Comparative Low Temperature Chart	2,5
S-67-4750	Bulk LP CO_2 Liquid Container Handling Precautions	9
S-67-4751	Bulk LP CO_2 Liquid Containers	9
S-67-4752	Approximate Liquid to Water Density Ratios	9
S-67-4753	Liquid To Gas Expansion Ratios	9

APPENDIX L

INSTRUCTIONAL TECHNIQUES

Using Audiovisual Materials Effectively

1. Plan

   Decide when and why audiovisual materials should be used.

2. Select

   Choose audiovisual material that best suits your requirements.

3. Preview

   Be knowledgeable about your material before using it.

4. Presentation

   Prepare class participants for what to observe.

5. Follow-through

   Discuss, summarize, test, and plan for related or future activities.

6. Repeat showing

   Show again for additional learning or to meet definite objectives when advisable.

The Chalkboard

Introduction.- The chalkboard is one of the most versatile and valuable audiovisual aids to be found in a Manned Spacecraft Center classroom. This device has kept its place in our modern space program because of its instructional value and convenience. No setting up, no moving from room to room, no danger of mechanical failure, and no special equipment are involved. Always handy, it is ready for use at a moment's notice.

Purpose.- The chalkboard can help visualize this gas-cryogen curriculum guide by the following means:

1. Presenting significant facts and principles such as new terms, objectives, procedures, outlines, and safety measures

2. Illustrating facts, ideas, and processes through the use of drawings, sketches, diagrams, and other visual symbols

3. Serving as a bulletin board to display assignments, announcements, questions, quiz item data, analyses, and so forth

4. Serving as a group or individual medium for planning, outlining, or summarizing

Techniques.- Among the chalkboard techniques which can be utilized effectively for presentation and variation of instruction are the following:

1. Comic or sketch figure
2. Grid
3. Hidden drawing
4. Pattern
5. Projection
6. Template

Suggestions.-

1. Be legible and recall that lettering is usually preferable to script writing.

2. Bear down on chalk, since faint writing is difficult to see.

3. Make letters and drawings large enough to be seen from all parts of the classroom.

4. Talk to the class participants, not the chalkboard, while working at the board.

5. Write in a straight line.

6. Remove unrelated material from the board.

7. Avoid chalkboard glare by examining illumination conditions and making corrections before the class session commences.

8. Take pains with drawings and diagrams when they require accuracy.

9. Avoid chalk screech by holding the chalk at an acute angle with the board and in line with the direction of writing.

10. Use colored chalk and shading where appropriate.

11. Stand at one side of what is written and use the pointer for emphasis so that materials appearing on the chalkboard are not concealed.

12. Develop complex ideas step by step, or stage by stage, for clarity.

13. Put complicated matter on the board before class convenes.

14. Have the boards cleaned often and regularly.

Summary.- The old-fashioned blackboard remains a giant in space-age education because it is one of the most powerful instructional tools available to Manned Spacecraft Center instructors. Resourceful Center instructors will think of this two-fold device as an "action board" for demonstration purposes as well as a short-term bulletin board for display purposes.

Field Trip

Introduction.- The ultimate success of a field trip depends upon its careful planning, the actual execution of the visit, and a review and an assessment of what was learned. During the trip, the class participants should see not only the location of the installation but also the operation of the facility or equipment which they have been studying.

Trip Planning.- The instructor(s) should perform the following tasks:

1. Contact the proper person(s) at the facility to be visited well before the date of visitation.

2. Establish a definite time and date for the proposed visit.

3. Arrange for an appropriate number of personnel to escort small group (if necessary) of class participants.

4. Discuss with facility personnel the operation and safety practices and problems of equipment to be observed and the types of information to be presented to class participants.

5. Discuss the objectives of the trip with the class participants.

6. Discuss with the class members what to observe and/or problems that can be answered or solved during the visit.

7. Review the safety precautions to be taken at the facility.

Executing the Trip.- The instructor(s) should also do the following.

1. Insure prompt arrival at the facility to be visited.

2. Make certain that the prearranged small groups of class members (if appropriate) stay with assigned facility personnel.

3. Encourage the class participants to comment or raise questions when clarification of further information is desired.

Trip Assessment.- Upon returning to the classroom from the trip, the instructor(s) should determine how meaningful the trip was. A class discussion of the field trip, a question and answer session, or even a short quiz are examples of approaches which could be taken in evaluating the trip.

Summary.- When properly planned, carefully executed, and meaningfully evaluated, the field trip can prove to be an invaluable and varied type of learning experience.

Film Utilization

Introduction.- The educational motion picture film, when properly used, can be one of the most effective teaching tools utilized by an instructor in this gas-cryogen course because of its wide range of possibilities. Through the use of sound, sight, motion, and color, the film makes it possible for an instructor to bring numerous facets of the aerospace world to the classroom for observation and study.

Effective Educational Film Utilization.- The instructor will want to do the following.

1. Be alert to the best sources of new films in the gas-cryogen area.
2. Know how to operate the motion picture projector.
3. Prepare the room where projection will take place for optimum comfort of the class participants with regard to acoustics, lighting, seating, and ventilation.
4. Set up the film objectives. Know what you are trying to teach through the use of a particular film and consider how the film is related to the interests and needs of the class. Also, ask yourself if the film is the best available audiovisual aid to use.
5. Preview the film and carefully plan for its use in the presentation.
6. Discuss the film with class participants prior to presenting it and briefly discuss:
    a. The purposes of the film
    b. What to look for and special problems, if any, noted in the film
    c. New words, phrases, or concepts
    d. A list of questions to be answered by the film
7. Ask yourself the following on the film screening.
    a. Is a second film showing advisable?
    b. Are there any misunderstandings to be corrected?
    c. Did class participants find the film worthwhile?
    d. Did learning result from viewing the film?

8. Recommend follow-through activities which should result from viewing the film such as further reading, further discussion, examining other cryogen-gas information or equipment, and viewing other audiovisual aids.

9. Assess the film for further use, keeping a file on films you have used helps. Perhaps a few notes placed on a file card may contain a brief synopsis of the film, your assessment, and comments for future use.

Conclusion.- When the educational motion picture film is properly planned, carefully presented, and meaningfully assessed, it can become an invaluable type of instructional experience and yield increased learning for gas-cryogen course participants.

Remember, too, that proper film utilization has implications for other projected materials used in this course, especially for the standard and/or 35-mm slides.

APPENDIX M

Suggested Classroom Needs for Gas-Cryogen Presentation

At the Manned Spacecraft Center, different rooms in various buildings may be used for conducting this gas-cryogen safety course. Regardless of its location, each room should be equipped basically with certain items, and, in addition, certain audiovisual aids are required.

Basic room equipment includes the following:

1. Illumination control
2. Air conditioning
3. Acoustic control
4. Electrical power outlets (5 minimum)
5. Appropriate seating accommodations for approximately 12 to 16 participants
6. Storage area for gas-cryogen material in the room itself or in space adjacent thereto
7. Lectern with light attachment (1)
8. Display table (1)
9. Small tables (2)

Different types of audiovisual aids will be required for presenting the course. The following are considered as appropriate:

1. Sixteen-millimeter sound motion picture projector (1)
2. Overhead transparency projector (1)
3. Opaque projector with pointer attachment (1)
4. Slide projector for 2- by 2-in. slides (1)
5. Tape recorder and tape — optional (1)
6. Projection screen (1)
7. Bulletin board (1)
8. Chalkboard, fixed or portable (1 but preferably 2)
9. Easel (1)
10. Flip chart (1)
11. Standard slide projector (1)

GLOSSARY

The terms which follow are among those frequently used in cryogenics and related fields, especially in connection with this course.

Absolute zero

The lowest temperature currently attainable at which all molecular activity is considered to cease [-459.7° F (-273.16° C)]

Air

The elastic, invisible mixture of gases, including nitrogen, oxygen, hydrogen, argon, carbon dioxide, neon, helium, and so forth, that surrounds the earth

Ambient

Surrounding, encircling. Thus, ambient temperature (or pressure) is the prevailing temperature (or pressure) surrounding the material or object concerned.

Boiling point

The temperature at which the vapor pressure of a liquid becomes equal to the pressure of the ambient atmosphere

Catalyst or catalytic agent

Any substance which by virtue of its presence affects the rate of a chemical reaction and which may be recovered practically unchanged at the end of the reaction

Contaminate

To make impure or unclean by coming in contact with something; for example, fumes from the cylinder were contaminating the air

Corrosion

The process in which a material acts upon another material in such a way as to destroy or damage it permanently; for example, acid destruction of the interior of a pipe or tubing installation

Critical temperature

That temperature above which a material can no longer be kept in liquid state, no matter how much pressure is applied

Critical pressure

The pressure under which a substance may exist as a gas in equilibrium with the liquid at the critical temperature

Cryogenics

The field that deals with the production of very low temperatures (usually below -150° F) and their effect on the properties of matter; also the field concerned with the practical application of very low-temperature processes and techniques

Cryostats

A cryostat is a device or system for establishing and maintaining a cryogenic temperature. Cryostats are broadly divided into open- and closed-cycle systems. An open-cycle system permits the cryogen to boil off into the atmosphere. Temperature is maintained by replenishing the liquefied gas from a storage vessel. Although these systems are much simpler to construct (often from parts in the lab) and generally have a lower initial cost, they can be permitted to boil off. A closed-cycle system recovers and reliquefies the boil-off vapors and thus provides a more economical installation.

Cryotrons

Superconductive four-terminal switching devices in which a magnetic field, produced by passing a current through two input terminals, controls the resistance between two output terminals

Dewar vessel

A multi-walled vacuum container designed to insulate its contents from the external temperature (essentially a sophisticated thermos bottle)

Flash point

The lowest temperature at which a liquid will release flammable vapors

Flammable

Replaces the expression "inflammable"

Freezing point

The temperature at which a material changes from the liquid to the solid state. Freezing point is slightly dependent upon pressure.

Heat of fusion

The heat required to convert a unit mass of substance from the solid state to the liquid state at a given pressure (and temperature)

Heat of sublimation

The heat required to convert a unit mass of substance from the solid state to the gaseous state

Heat of vaporization

The heat required to convert a unit mass of substance from the liquid state to the gaseous state at a given pressure (and temperature)

Hypergolic

The term applied to materials which undergo spontaneous ignition when mixed with each other

Laminar

A trade name for temperature-control readings

Laminate

Two or more layers of a base material such as fiberglass or cloth impregnated or coated with a synthetic resin and bonded together by means of heat and/or pressure

Liquefied gases

Liquid form of substances which under usual conditions of pressure and temperature are found as gases; for example, liquid nitrogen

Liquid propellant

A chemical in liquid form used as a fuel, oxidizer, or monopropellant to provide the combustion necessary for the production of thrust by a rocket engine

Liquid to gas ratio

A comparison of the volume of the liquid state of a material to the volume of its gaseous state at a pressure of 1 atmosphere. For example, 1 cu ft LOX will evaporate into 862 cu ft CO_2 at atmospheric pressure; therefore, the liquid to gas ratio is 1:862.

Nylon

Generic name for polyamide polymer

Oxidizer

A material which makes possible the combustion of fuel by supplying oxygen; in a wider sense in rocket usage, any material serving this function, whether or not oxygen is involved

Monopropellant

A single material used to power a rocket engine

Propellant

A fuel or an oxidizer used by a rocket engine to provide thrust

Solid propellant

A solid mixture of fuel and oxidizer cured in the form of a block or grain which fits into the combustion chamber of the rocket

Specific gravity

The ratio of the weight of a material to the weight of an identical volume of water at a given temperature

Superconductivity

The phenomenon by which some substances suddenly lose all electrical resistance when their temperatures are reduced. These transitions occur at temperatures lower than the temperature of liquid hydrogen

Teflon

A trade name for thermoplastic fluorocarbon plastics

Toxic

Poisonous, or causing poisoning

Transfer lines

Transfer lines range in complexity from a piece of rubber hose, usable over short distances (not for LHe), to sophisticated, vacuum-jacketed structures. When working with LHe, special care is required if transfer is to be accomplished economically. A vacuum-jacketed line is a necessity. Maximum economy can be achieved with a well insulated line if it is pre-cooled at a rate consistent with safety and the capacity of the equipment. Transfer lines are available in rigid, segmented, or flexible sections, and are usually constructed to suit the requirements of the particular laboratory or system.

Triple point

The particular condition under which a substance can be presented in any or all phases (gaseous, liquid, or solid)

Vapor pressure

The pressure exerted by the evaporation of a liquid at any given termperature

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NOTATION

This curriculum guide has been designed for a gas-cryogen course — believed to be the first of its kind. Both the authors and the Manned Spacecraft Center's Safety Office would greatly appreciate constructive suggestions and comments which could enhance the course and contribute to a better and more effective manual in which safety is of paramount importance.